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ADVANCED WASTE WATER TREATMENT AS PRACTICED AT SOUTH TAHOE

Russell L. Culp, et al

South Tahoe Public Utility District
South Lake Tahoe, California

August 1971

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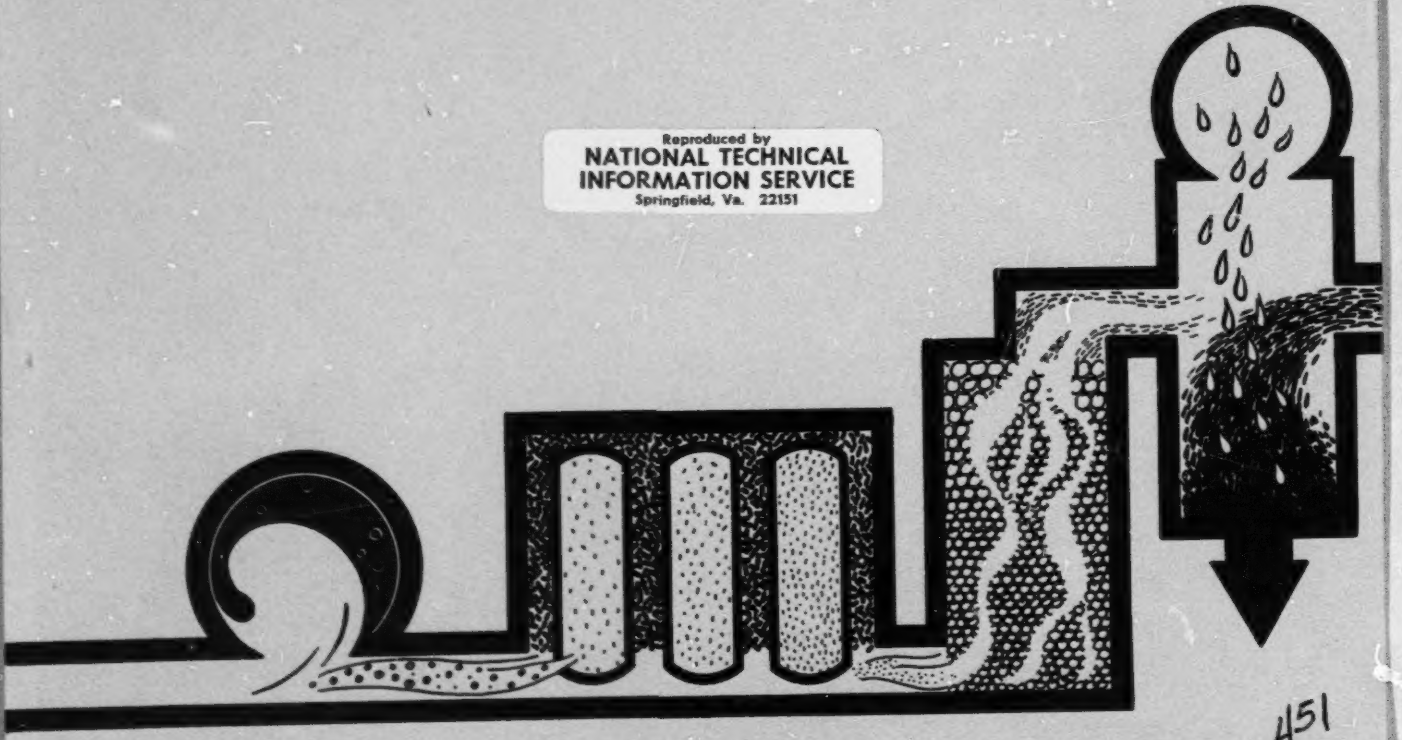

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16. Abstract A 7.5 mgd advanced wastewater treatment plant at South Lake Tahoe, California has been in uninterrupted operation for three years. Chemical treatment, mixed media filtration, and granular carbon adsorption have been shown to be efficient , reliable, and economical processes for wastewater treatment. A degree of reliability and flexibility comparable to that achieved in electric power generation and water purification has been achieved by appropriate selection and sequencing of unit processes and proper plant design. Plant bypasses have been eliminated. Bacteria and viruses have been entirely eliminated from the effluent by small chlorine dosages. Lime has been recalcined in a multiple hearth furnace without air pollution, and granular activated carbon has been successfully regenerated and reused, with stack gasses scrubbed to meet air pollution standards. The entire plant produces only clean water, sterile ash, and harmless gases. Reclaimed wastewater has been used to form a recreational lake, certified for all water contact sports by regular testing, and free of algal blooms. The wastewater treatment cost has been approximately twice the cost of conventional wastewater treatment, but the project has demonstrated that man's wastes need no longer degrade the environment if genuine desire and determination to solve the problem is applied. (Lowry-Texas)

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27 *Abstract*

This report presents the results from three years operation of a 7.5 mgd advanced wastewater treatment plant at the South Tahoe Public Utility District in South Lake Tahoe, California.

The work includes a comprehensive study of the efficacy, reliability, and economy of a tertiary sequence of treatment consisting of conventional activated sludge, followed by lime treatment for phosphate removal, ammonia stripping, two-stage recarbonation, mixed media filtration, granular activated carbon adsorption of dissolved organics, and chlorination. Granular carbon is thermally regenerated and resued, spent lime mud is recalcined and reused, and all waste organic and chemical sludges are incinerated to sterile, inert ash.

Quality of the reclaimed water is consistently very high. It is sparkling clear, low in algal nutrients, free of color, odor, bacteria, and viruses, and is suitable for many, if not all, types of reuse.

The project clearly demonstrates that all of the necessary technology is now available to completely control water pollution from all domestic and most industrial wastewaters provided that a genuine desire exists to do so, and that adequate leadership and financing are provided.

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ADVANCED WASTEWATER TREATMENT AS PRACTICED AT SOUTH TAHOE

by

SOUTH TAHOE PUBLIC UTILITY DISTRICT
SOUTH LAKE TAHOE, CALIFORNIA

for the

WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

Project 17010 ELQ (WPRD 52-01-67)

August 1971

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This report has been reviewed by the Environmental Protection Agency and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

ABSTRACT

This report presents the results from three years operation of a 7.5 mgd advanced wastewater treatment plant at the South Tahoe Public Utility District in South Lake Tahoe, California.

Two principal purposes of the project are to evaluate the recovery and reuse of lime as a coagulant in tertiary treatment, and to investigate ammonia stripping as a means for nitrogen removal from tertiary effluent.

The work also includes a comprehensive study of the efficacy, reliability, and economy of a tertiary sequence of treatment consisting of conventional activated sludge, followed by lime treatment for phosphate removal, ammonia stripping, two-stage recarbonation, mixed media filtration, granular activated carbon adsorption of dissolved organics, and chlorination. Granular carbon is thermally regenerated and reused, spent lime mud is recalcined and reused, and all waste organic and chemical sludges are incinerated to sterile, inert ash.

Quality of the reclaimed water is consistently very high. It is sparkling clear, low in algal nutrients, free of color, odor, bacteria, and viruses, and is suitable for many, if not all, types of reuse.

The project clearly demonstrates that all of the necessary technology is now available to completely control water pollution from all domestic and most industrial wastewaters provided that a genuine desire exists to do so, and that adequate leadership and financing are provided.

This report was submitted in fulfillment of Project Number 17010 ELQ, Grant WRPD 52-01-67, under the partial sponsorship of the Water Quality Office, Environmental Protection Agency.

CONTENTS

Section	Title	Page
I	CONCLUSIONS	1
II	RECOMMENDATIONS	3
III	INTRODUCTION	5
IV	HISTORY, PURPOSES, AND IMPLEMENTATION OF THE TAHOE PROJECT	7
	HISTORY	7
	Local Conditions	7
	Seeking A Plan	10
	Advanced Waste Treatment	10
	Plant Overloaded	11
	Solids Disposal System	11
	Nitrogen Removal	12
	Effluent Disposal	12
	Alternate Export Routes	13
	IMPLEMENTATION	15
	PURPOSES	15
	Local Purposes	15
	Broader Purposes	18
V	SELECTION AND INTEGRATION OF UNIT PROCESSES	19
	General	19
	Effluent Quality Required	21
	Reliability	22
	Status of Process Development	24
	Requirements for Ultimate Disposal of Sludge	25
	Process Compatibility	26
	Process Flexibility	28
	Costs	28
	Awkward Process Combinations	29
	Storage	31
	Disinfection	32
	Summary	32
VI	THE TAHOE PROCESS FOR WASTEWATER RECLAMATION	33
	Water Reclamation Plant	33
	Liquid Processing	33
	Solids Handling System	38

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CONTENTS

Section	Title	Pages
VII	PLANT DESIGN DATA	41
VIII	EXPORT SYSTEM	47
	Description	47
IX	OPERATOR TRAINING	53
	Introduction	53
	South Tahoe Training Program	53
	Operator Goals	55
X	SAMPLE COLLECTION AND ANALYSIS	57
	Automatic Sampling System	57
	Schedule of Sampling and Testing	57
XI	TEST PROCEDURES	63
	GENERAL	63
	CALCIUM OXIDE (EDTA Method)	63
	Procedure	63
	Calculation	63
	Reagents	63
	Standardization	64
	APPARENT DENSITY TEST FOR ACTIVATED CARBON	64
	CARBON ASH ANALYSIS	65
	Procedure	65
	Notes on Method	65
	CARBON ISOTHERM PROCEDURE	65
	THE IODINE NUMBER OF ACTIVATED CARBON	67
	Procedure	67
	Notes on Method	68
	Reagents and Equipment	68
XII	PRIMARY TREATMENT	71
	Physical	71
	Treatment Efficiency	71
XIII	ACTIVATED SLUDGE SECONDARY TREATMENT	73
	Physical	73
	Operational Practices	73
	Treatment Efficiency	73

CONTENTS

Section	Title	Page
XIV	DEWATERING AND INCINERATION OF WASTE ORGANIC SOLIDS	77
	Physical	77
	Operational Practices	77
	Stack Sampling Results	79
XV	CHEMICAL TREATMENT	81
	Primary Treatment	81
	Activated Sludge	82
	Lime Coagulation and Clarification of Secondary Effluent	84
	Methods Used For Data Collection	85
	Optimum Lime Dose	86
	Effects of Recycle Water	86
	Maintenance of Lime Mud Lines	101
	Additional Benefits of Chemical Coagulation and Clarification	101
	Point of Polymer Application	116
	Summary and Conclusions	116
XVI	TWO STAGE RECARBONATION	119
	Methods Used for Data Collection	119
	Results of Jar Tests	122
	Results of Plant Scale Testing	128
	Calcium Stability	134
	Desired pH Level	135
	Chemical Addition	135
	Summary and Conclusions	136
XVII	LIME RECOVERY AND REUSE	139
	General	139
	Physical System	139
	Operating Practice	143
	Lime Mud Thickening	143
	Lime Mud Classification and Dewatering	144

CONTENTS

Section	Title	Page
XVII (cont.)	Chemical Addition	144
	Classification Evaluation	144
	Classification Evaluation Results	145
	Lime Mud Recalcining	153
	Optimum Furnace Conditions	155
	Conclusions	161
XVIII	NITROGEN REMOVAL	163
	General	163
	Ammonia Stripping Tower Physical Description	163
	Tower Performance	166
	Operational Problems	172
	Tower Off-Gases	175
	Summary and Conclusions	175
XIX	MIXED MEDIA FILTRATION	177
	General	177
	Filter Role	178
	How Mixed-Media Filters Act	179
	Separation Beds at South Tahoe	180
	Special Separation Bed Evaluation	184
	Test Results Separation Bed Evaluation	186
	Summary - Separation Bed Evaluation	192
	Filtration Summary	196
XX	GRANULAR ACTIVATED CARBON ADSORPTION AND REGENERATION	199
	Carbon Adsorption System	199
	Carbon Regeneration System	201
	Carbon Adsorption Operating Practices	206
	Carbon Regenerating Operating Practices	208
	Carbon Column Maintenance	210
	Carbon Regeneration Maintenance	211
	Sampling and Data Collection	211
	Average Results of Carbon Adsorption and Regeneration	213
	Effect of Carbon Regeneration Cycles on Organics Removal	215

CONTENTS

Section	Title	Page
XX (Cont.)	Carbon Column Loading Rate Investigation	218
	Carbon Loading and Regeneration Over an Extended Period of Time	218
	Long Range Ash Build-Up	240
	Carbon Losses Due to Regeneration and Physical Handling	242
	Summary and Conclusions	252
XXI	VIRUS REMOVAL	257
	General	257
	Design Consideration for Virus Removal	266
	Actual Virus Removals in Plant Operation	267
XXII	DISINFECTION	271
	General	271
	Chlorine Feed Facilities	273
	Results of Chlorination	273
XXIII	FINISHED WATER QUALITY	277
	Sampling and Analysis	277
	Summary Finished Water Quality	298
XXIV	INDIAN CREEK RESERVOIR	301
	General	301
	Study and Monitoring Procedures	301
	Visual Observations	303
	Physical and Chemical Tests	304
	Irrigation	311
	Rainbow Trout Fishery	311
	Results of Lake Tahoe Area Council Study	315
	Recreational Use	319

CONTENTS

Section	Title	Page
XXV	CAPITAL AND OPERATING COSTS FOR CONVENTIONAL AND ADVANCED WASTE TREATMENT	323
	Introduction	323
	Assumptions for Capital Costs	324
	Capital Costs	324
	Assumptions for Operating Costs	326
	Operating Cost Data Collection and Analysis	327
	Unit Operating Costs	329
	Primary Treatment	329
	Secondary Treatment	329
	Organic Sludge Dewatering	332
	Organic Sludge Incineration and Disposal	332
	Overall Costs - Organic Sludge Dewatering, Incineration, and Disposal	336
	Lime Coagulation	336
	Lime Mud Dewatering	336
	Lime Mud Recalcining	340
	Overall Costs - Lime Dewatering and Recalcining	340
	Nitrogen Removal by Ammonia Stripping	340
	pH Adjustment by Recarbonation	343
	Mixed Media Filtration	343
	Carbon Adsorption	347
	Carbon Regeneration	349
	Disinfection by Chlorine	353
	Summary	353
	Increase in Construction Costs at South Lake Tahoe	354
XXVI	ACKNOWLEDGEMENTS	361

CONTENTS

Section	Title	Page
XXVII	REFERENCES	365
XXVIII	LIST OF PUBLICATIONS RESULTING FROM DEMONSTRATION GRANT PROGRAM	379
APPENDIX A	TABULATION OF VISITORS TO PLANT	383
APPENDIX B	TABULATIONS OF DAILY LABORATORY AND FLOW DATA	385
APPENDIX C	CARBON ADSORPTION ISOTHERMS	419

TABLES

No.	Title	Page
1	Effluent Quality Required	21
2	Average Raw Sewage Characteristics 1970	71
3	Average Plant Performance for COD Removal	75
4	Organic Sludge Furnace Operating Data	79
5	Stack Sampling Results	80
6	Plant Scale Effect of Recycle Streams on Average Phosphorus Removals	91
7	Effect of Recycle Water on Turbidity vs Lime Dose	93
8	Average Effect of Recycled Water on Chemical Clarifier Efficiency	95
9	Average Effect of Very High Turbidity and Phosphorus in the Recycle Water	98
10	Average Efficiency of Chemical Clarifier with Recycle Water Added to Floc Basin	99
11	Average Efficiency of Chemical Clarifier with Recycle Water Added to Primary Clarifier	100
12	Stability Index and Marble Test - Scrubber Water and Lime Mud Thickener Overflow	102
13	Average Performance of The Two Stage Recarbonation System	132
14	Scrubber Water Ortho Phosphorus Content, mg/l PO_4-P	152
15	Lime Recalciner Operating Data	154
16	Effect of Temperature on Recalcined Lime Activity at a Constant Feed and Rabble Rate	158
17	Effect of Rabble Rate on Recalcined Lime Activity at a Constant Feed Rate	159
18	Effect of Feed Rate on Recalcined Lime Activity at 1900° F and 1.5 RPM Rabble Rate	160
19	Design Data Full Scale Ammonia Stripping Tower	164
20	Low Temperature Ammonia Stripping at South Lake Tahoe Plant	167
21	Typical Removals by Separation Beds	185
22	Removal Efficiencies of Two Separation Beds in Series at 8 - 64 ppm Dry Alum Dosages	185
23	Pounds of Various Substances Removed Per Pound of Dry Alum Fed	192
24	A Comparison of COD and MBAS Removal Efficiency Between First Cycle CC-5 and Third Cycle CC-6	216

TABLES

No.	Title	Page
25	A Comparison of COD and MBAS Removal Efficiency Between Second Cycle CC-5 and Fourth Cycle CC-6	217
26	Average Carbon Efficiency Per Regeneration Period	222
27	Average Carbon Furnace Parameters Per Regeneration Period	228
28	Organic Loading and Reactivation Effect on Iodine Number	234
29	Furnace Operating Conditions for Four Batch Regeneration Cycles	236
30	Percent Ash Over Four Carbon Regeneration Cycles	241
31	Carbon Losses During Batch Regeneration Periods Which Included Regeneration of First Cycle Make-up Carbon	245
32	Average Mean Particle Diameters of Carbon	247
33	Mean Particle Diameter of Carbon at Various Points in Regeneration System	248
34	Sieve Analysis of Third Cycle Carbon from CC-6 at Various Points in the Regeneration System	250
35	A Comparison of Water Quenching of 4th Cycle Regenerated Carbon with Air Cooling	251
36	Virus Sampling - 1969 South Tahoe Public Utility District Water Reclamation Plant	268
37	Monthly Summary of Bacteriological Tests	275
38	Reclaimed Water Quality April - September 1968	278
39	Reclaimed Water Quality October 1968 - March 1969	279
40	Reclaimed Water Quality April - September 1969	280
41	Reclaimed Water Quality October 1969 - March 1970	281
42	Reclaimed Water Quality April - September 1970	282
43	Reclaimed Water Quality October - December 1970	283
44	Summary of Laboratory Analyses 8 July 1968 - 1 October 1968	284
45	Summary of Laboratory Analyses 1 October 1968 - 1 January 1969	285
46	Summary of Laboratory Analyses 1 January 1969 - 1 April 1969	286
47	Summary of Laboratory Analyses 1 April 1969 - 1 July 1969	287
48	Summary of Laboratory Analyses 1 July - 1 September 1969	288

TABLES

No.	Title	Page
49	Summary of Laboratory Analyses 1 October 1969 - 1 January 1970	289
50	Typical Quality of Reclaimed Water	297
51	Effluent Storage Reservoir Laboratory Analyses 1968	305
52	Effluent Storage Reservoir Laboratory Analyses March 28, 1969	306
53	Temperature and Dissolved Oxygen Profiles of Indian Creek Reservoir	307
54	Water Quality of Indian Creek Reservoir and Stevens Lake	308
55	Capital Costs for Conventional and Advanced Waste Treatment Plant at 7.5 MGD Design Capacity	325
56	Percent Operational Labor Division per Treatment Phase	328
57	Unit Costs 1969 and 1970	330
58	Operating and Capital Costs Primary Treatment at 7.5 MGD	331
59	Operating and Capital Costs Secondary Treatment at 7.5 MGD	333
60	Operating Costs Organic Sludge Dewatering at 7.5 MGD	334
61	Operating Costs Organic Sludge Incineration at 7.5 MGD	335
62	Operating and Capital Costs Organic Sludge Dewatering and Incineration at 7.5 MGD	337
63	Operating and Capital Costs, Lime Coagulation at 7.5 MGD	338
64	Operating Costs Lime Mud Dewatering	339
65	Operating Costs Lime Mud Recalcining at 7.5 MGD	341
66	Operating and Capital Cost Lime Mud Dewatering and Recalcining	342
67	Actual Operating and Capital Cost Ammonia Stripping at 7.5 MGD Under Intermittent Conditions	344
68	Operating Costs For Ammonia Stripping at 7.5 MGD For Continuous Operation	345
69	Operating and Capital Costs Recarbonation at 7.5 MGD	346
70	Operating and Capital Costs Filtration at 7.5 MGD	348

TABLES

No.	Title	Page
71	Operating and Capital Costs Carbon Adsorption at 7.5 MGD	350
72	Operating and Capital Costs Carbon Regeneration at 7.5 MGD	351
73	Operating and Capital Costs Carbon Regeneration per Ton of Carbon Regenerated	352
74	Total Operating Costs Conventional Wastewater Treatment at 7.5 MGD	355
75	Total Operating Costs Advanced Wastewater Treatment at 7.5 MGD	356
76	Total Operating and Capital Costs for Conventional and Advanced Waste Treatment at the South Tahoe Water Reclamation Plant for the 7.5 MGD Design Capacity in 1969 and 1970	357
77	Miscellaneous Operating Costs for Conventional and Advanced Waste Treatment	358
78	Actual Construction and Equipment Costs at the 7.5 MGD South Lake Tahoe Water Reclamation Plant by Contract Completion Dates	360

FIGURES

No.	Title	Page
1	Aerial View of South Lake Tahoe	8
2	South Tahoe Public Utility District Service Area	9
3	Organization for Project Implementation	16
4	Board of Directors in Session	17
5	Schematic Flow and Process Diagram	34
6	Luther Pass Pump Station	48
7	Indian Creek Reservoir During Initial Filling	50
8	Iodine Correction Curve	70
9	Solids Handling - Primary and Secondary Sludge	78
10	Chemical Rapid Mix and Clarifier with Secondary Clarifier in Foreground and Nitrogen Removal Tower in Background	83
11	Phosphorus Removal from Secondary Effluent versus Lime Dose	87
12	Turbidity Removal from Secondary Effluent versus Lime Dose	88
13	pH versus Lime Dose	89
14	Effect of Recycle Water on Phosphorus Concentration vs Lime Dose	92
15	Total Phosphorus Removal vs Calcium Oxide Dose	96
16	Total Phosphorus Removal vs Clarifier Overflow Rate	97
17	Pounds of Total COD Applied vs Percent COD Removal	103
18	Total BOD Removal vs Lime Dose	105
19	Soluble BOD Removal vs Lime Dose	106
20	Particulate BOD Removal vs Lime Dose	107
21	Total COD Removal vs Lime Dose	108
22	Soluble COD Removal vs Lime Dose	109
23	Particulate COD Removal vs Lime Dose - Recycle Stream to Floc Basin	110
24	Total COD Removal vs Lime Dose - Recycle Streams to Primary	111
25	Soluble COD Removal vs Lime Dose - Recycle Streams to Primary	112
26	Particulate COD Removal vs Lime Dose - Recycle Streams to Primary	113
27	Organic Suspended Solids Removal vs Lime Dose	114
28	Organic Suspended Solids Removal vs Clarifier Overflow Rate	115

FIGURES

No.	Title	Page
29	Recarbonation Schematic	120
30	Ammonia Stripping Tower and Recarbonation Basins - Normal Operation	121
31	pH vs Reaction Time	123
32	pH vs Sludge Produced	124
33	pH vs Total Hardness	125
34	Sludge Produced vs Hardness Reduction	126
35	pH vs Alkalinity	127
36	Polyelectrolyte Dosage vs Sludge Produced	129
37	Alum Dosage vs Sludge Produced	130
38	Hardness vs Alum Dosage in Jar Tests	131
39	First Stage pH vs First Stage Stability Index	134
40	Solids Handling Building	140
41	Solids Handling - Lime Sludge	141
42	Furnace Control Panel	142
43	Percent Solids Captured vs Flow Rate to Centrifugal	146
44	Effect of Centrifugal Capture on the Change in Calcium Oxide Content of the Centrifugal Cake	148
45	Percent Solids Captured vs Percent of Usable Calcium in Feed Conveyed to Furnace	149
46	Percent Solids Captured vs Percent of PO_4 in Feed Wasted in Centrate	150
47	Percent Solids Captured vs Percent of Magnesium in Feed Wasted to Centrate	151
48	Virgin Lime Slaking Rate Test	157
49	Nitrogen Removal Tower	165
50	Percent Ammonia Removal vs Cubic Feet of Air per Gallon Wastewater Treated for Various Depths of Packing	169
51	Percent Ammonia Removal vs Surface Loading Rate for Various Depths of Packing	170
52	Effect of Water Temperature on Ammonia Stripping	171
53	Mixed Media Filter Before and After Initial Backwashing	181
54	Separation Beds Filter Cycle	182
55	Exterior View of Separation Beds, Decanting Tank, and Tertiary Building	183
56	Percent Removal of PO_4-P vs Dry Alum Dosage Across Both Separation Beds	187

FIGURES

No.	Title	Page
57	Percent Removal of Soluble PO_4-P vs Dry Alum Dosage Across Both Separation Beds	188
58	Percent Removal of COD vs Dry Alum Dosage Across Both Separation Beds	189
59	Percent Removal of BOD vs Dry Alum Dosage Across Both Separation Beds	190
60	Length of Separation Bed Run vs Dry Alum Dosage	191
61	Pounds of PO_4 Removed Per Hour vs Pounds of PO_4 Applied Across Both Separation Beds	193
62	Pounds of Suspended Solids Removed Per Hour vs Pounds of Suspended Solids Applied Across Both Separation Beds	194
63	Pounds of Turbidity Removed Per Hour vs Pounds of Turbidity Applied Across Both Separation Beds	195
64	Carbon Columns	200
65	Carbon Columns Normal Upflow Operation	202
66	Section Through Carbon Column	203
67	Carbon Furnace and Quench Tank	204
68	Carbon Regeneration System	205
69	Carbon Defining Tank	207
70	MBAS Removal for Controlled Loading Rates	219
71	COD Removal for Controlled Loading Rates	220
72	A Comparison of COD Efficiency, Iodine No., and Carbon Dosage by Carbon Regeneration Periods	223
73	A Comparison of MBAS Efficiency, Iodine No., and Carbon Dosage by Carbon Regeneration Periods	224
74	Increase in Spent Carbon Iodine Number by Thermal Reactivation	225
75	Carbon Regeneration Cycles	226
76	Isotherms for Virgin and Regenerated Carbon	230
77	Isotherm Spent and Regenerated Ultimate COD Capacity vs Four Regeneration Cycles	231
78	Isotherms for Regenerated Carbon	232
79	Isotherms for Regenerated Carbon	237
80	Isotherm Spent and Regenerated Ultimate MBAS Capacity vs Four Regeneration Cycles	238
81	Isotherms for Regenerated Carbon	239
82	Percent Loss of Carbon vs Carbon Regeneration Cycles	244

FIGURES

No.	Title	Page
83	BOD Removals Through Plant - 1969	290
84	COD Removals Through Plant - 1969	291
85	Suspended Solids Removals Through Plant - 1969	292
86	MBAS Removals Through Plant - 1969	293
87	Phosphorus Removals Through Plant - 1969	294
88	Ammonia Nitrogen Removals Through Plant and Reservoir - 1969	295
89	Aerial View of Indian Creek Reservoir	302
90	Rainbow Trout From Indian Creek Reservoir	312
91	Sailboating on Indian Creek Reservoir	320
92	Swimming in Indian Creek Reservoir	321

SECTION I

CONCLUSIONS

1. In actual practice, reclaimed wastewater has been used to create a recreational lake in which algal growths have been successfully controlled by nutrient removal in the treatment plant and reservoir.

2. The reclaimed water is safe for all water contact sports such as fishing, boating, swimming, and water skiing, and has been officially approved for such purposes by the California Water Resources Control Board.

3. Chemical treatment, mixed media filtration, and granular carbon adsorption are efficient, reliable, and economical processes for tertiary wastewater treatment. The reliability and ease of control of these methods are very much greater than those for conventional biological treatment processes.

4. By appropriate selection and sequencing of unit processes and by proper plant design, wastewater treatment can be made fail-safe. Plant bypasses can be eliminated. A degree of reliability and flexibility in operation can be attained which is comparable to that achieved in power generation facilities and in water purification plants supplying water to the public.

5. Bacteria and virus can be entirely eliminated from adequately pretreated wastewaters by small doses of chlorine, properly applied, even in the presence of relatively high concentrations of ammonium ion.

6. Organic sludges from primary and secondary wastewater treatment can be incinerated to insoluble sterile ash without creating air pollution problems.

7. Lime used in wastewater treatment can be recalcined and reused. In small plants, such as the one at Tahoe, this avoids the problems and saves the costs which would otherwise be involved in lime sludge disposal. In larger plants, it can also reduce the cost of lime. Lime can be reclaimed in a multiple hearth furnace without air pollution.

8. Granular activated carbon used to adsorb organics from waste-

water can be thermally regenerated and successfully reused. Stack gases can be scrubbed to meet air pollution control standards.

9. Operation of advanced wastewater treatment processes as employed at Tahoe is less difficult than the operation of activated sludge systems. On the job training of locally available personnel has provided eminently satisfactory plant operation. The plant has operated without interruption for 3 years with the production of a reclaimed water which has continuously and without exception met the extremely high water quality standards established by the regulatory agencies.

10. The Tahoe plant has clearly demonstrated the fact that there is no need for wastewaters or their treatment by-products to pollute the environment in any manner. The means are available to prevent it. The Tahoe Process has only three end products; high quality water, insoluble sterile ash, and harmless stack gases.

11. The cost of even the highest degree of wastewater treatment is not a valid argument against it, rather it is a weak excuse for inaction. At a 7.5 mgd scale, the cost of treatment as practiced at Tahoe is slightly more than twice the low cost of conventional secondary treatment, but the cost benefits resulting from completely pollution-free operation are more than doubled. The cost of treatment is only one part of the total overall costs for wastewater collection, transport, and disposal. Even with the most advanced treatment, the cost of sewer service is the least of all common utilities including electric power, water, gas, and telephone. The costs to provide the necessary degree of treatment are reasonable and should not be a deterrent to the solution of pollution control problems.

12. To satisfy discharge and other environmental requirements less stringent than those at Tahoe, the advanced treatment processes can be appropriately reduced to suit local conditions with a resulting lowering of the costs involved.

13. The successful completion of pollution control projects depends on many important factors. The foremost of these is the genuine desire and determination of the members of the politically responsible governing body to solve the problem. They must also know how to solve the problem, and how to gain the necessary public support. They must have the benefit of competent engineering, legal, and financial advice. They must seek, train, and retain qualified personnel to properly operate and maintain the completed facilities.

SECTION II

RECOMMENDATIONS

The great motivating force for the Tahoe Demonstration Project was to find practical solutions to water pollution control problems. Although basic and applied research was involved to a limited extent, the principal effort at Tahoe has been to bridge the gap between scientific knowledge and discovery and its practical use and application in the field. This was basically an engineering design problem to develop methods and equipment to make use of new processes which had progressed only to the laboratory or pilot plant stage. This has been done. Chemical treatment for clarification or phosphorus removal, ammonia stripping (at temperatures above 32°F and with provisions for scale removal), recarbonation, mixed media filtration, granular carbon adsorption, lime recovery and reuse, sludge incineration, and carbon regeneration and reuse have all been shown to be efficient, reliable, and economical processes for use where required. Proven methods are now at hand to solve most, if not all, water pollution problems. The crying need at this time is for the widespread use of these demonstrated techniques to provide clean water. This is the message and principal recommendation of this report.

It is obvious from a reading of this report that nitrogen removal is the area which presently requires the most attention at this time. Despite the temperature limitations of ammonia stripping and the scaling problems involved, this method for nitrogen reduction for large concentrations of ammonia is by far the most economical and reliable to be developed to date. Unless, or until, other methods are developed which may prove to be better, further development and demonstration work should be done in this area. One approach to the calcium carbonate scale removal problem is simply to design or use a tower in which the packing is accessible for cleaning. At Tahoe it is proposed that the planned future second section of tower be built to provide full treatment capacity using a steel frame and plastic pipe packing. The packing would be factory pre-fabricated in modules which can be rolled in and out of the tower structure for cleaning by hosing down with a pressure stream of water. If this proves to be satisfactory, then the existing section of tower would be repacked with the new material. At times when the air temperature is below 32°F and the tower is not operative, the ammonia would be removed by break-point chlorination as described in the final report of FWPCA Grant WPP-85 for an earlier (1965-67) Tahoe project. It is recommended that this work be done immediately.

Indications are that water of quality suitable as a supplemental source of supply for potable water purification plants can be produced from wastewater by advanced treatment systems. However, much further study is needed of the tolerable levels of biological and chemical substances that may be present in wastewater; such as trace elements, pesticides, carcinogens, antibiotics, hormones, viruses, and materials not yet studied. The effects of various commercial and industrial wastes found in many urban wastewaters also need considerable investigation. The findings of studies in these areas will also be valuable in evaluating the safety of badly polluted surface water supply sources. Extensive studies are urgently needed in this area. They are principally of a research nature and are of a type which can be done by only a relatively few persons, most of whom are employed by EPA, by universities, or by private research organizations. It is strongly recommended that this research be done, so that when it becomes necessary in the future to supplement water supply sources with reclaimed water the questions regarding safety will all be answered.

SECTION III

INTRODUCTION

Today there is widespread public recognition of the gross inadequacies of conventional secondary sewage treatment processes in protecting the environment under many circumstances and the need for the practical application of new treatment methods which produce reclaimed water of superior quality.

At Lake Tahoe this need became apparent about ten years ago because of special local conditions which will be described in more detail later in this report. As a result, research and pilot plant studies were undertaken in 1961 to reveal possible new processes for wastewater reclamation. It was found that a tertiary sequence of treatment including conventional activated sludge followed by chemical treatment, mixed-media filtration, and granular carbon adsorption produced remarkable improvements in water quality. These improvements included virtually complete removal of suspended solids, BOD, bacteria, and other substances only partially removed by secondary treatment. In addition, good removals were obtained of COD, color, odor, viruses, phosphates, MBAS, and other substances which are relatively unaffected by secondary treatment.

In 1963, a 2.5 mgd tertiary plant was designed for the South Tahoe Public Utility District incorporating these processes, plus facilities for thermal regeneration of granular activated carbon for flows up to 10 mgd. This plant was built in 1964 and 1965 and was placed into operation during the summer of 1965.

In April 1965, further laboratory, pilot plant, and full-scale plant studies were initiated at Tahoe with WQO, EPA demonstration grant funds. These studies included recovery and reuse of coagulant, nitrogen removal, and data collection in connection with full-scale carbon regeneration and reuse.

In 1966, plans and specifications were prepared to expand the capacity of the entire South Tahoe plant from 2.5 to 7.5 mgd. Facilities were planned for the recovery and reuse of lime as a coagulant and for the incineration of all sludge produced. These plant additions were completed and placed into operation on March 31, 1968. Also an experimental ammonia stripping tower with a nominal capacity of only 3.75 mgd (one half that of the basic plant) was built and placed into operation in November 1968.

This 7.5 mgd Water Reclamation Plant of the South Tahoe Public Utility District is the largest and most complete scale advanced wastewater treatment plant in the world, and was the first to be placed into operation. It has been designated as a National Demonstration Plant by the WQO, EPA under the Clean Waters Restoration Act.

WQO, EPA Demonstration Grant WRPD 52-01-67 not only provides for studies of recovery and reuse of lime as a coagulant and ammonia stripping, but also for complete detailed studies and reporting of the entire plant operation including costs for a three year period ending February 1971.

This report includes: a discussion of the history and purpose of the Tahoe project, a description of the process used, design data for the plant and export system, an outline of the on-the-job training of plant personnel, a description of sample collection techniques and test procedures employed, detailed descriptions of each liquid processing step and each solids handling procedure, detailed results of treatment and plant operation, complete data on actual construction and operating costs, information on the prolonged storage of reclaimed water in Indian Creek Reservoir, conclusions and recommendations, and other miscellaneous related information.

SECTION IV

HISTORY, PURPOSES, AND IMPLEMENTATION OF THE TAHOE PROJECT.

HISTORY.

Local Conditions. Lake Tahoe is a beautiful alpine lake located high in the Sierra Nevadas straddling the California - Nevada boundary. Tahoe has not joined the list of ruined lakes. It is still one of the clearest purest lakes in the world. During the past decade many individuals have exercised great effort to assure its long and useful life, not to be sullied by the activities of man. This is the story of one group which has devoted the past ten years to developing a project to collect, treat and remove the treated sewage from the south shore area of Lake Tahoe.

Lake Tahoe Basin has an area of 506 square miles - 314 are land and 192 represent the water surface. The lake's man-made boundaries make a complex political problem; they include two states, five counties and over 65 local, State and Federal agencies - each exercising some jurisdiction over the land and water in the basin. Six local public agencies provide some degree of sewerage service. Three of the agencies are in Nevada and three in California. The South Tahoe Public Utility District is the largest and most active of the six agencies.

The District organized in 1951, consisted of 140 acres, with an assessed value of $1.14 million. It now contains over 21,000 acres, assessed at more than $80 million.

The District represents over half the developable land in the basin. The area has grown rapidly due to the increase in leisure time and year-round recreation, coupled with improved all year access by automobile and other forms of transportation. Figure 2 shows the present boundaries and location of the District.

In 1960, the District started operating a new 2½-mgd activated sludge treatment plant, which replaced two redwood septic tanks that had served as treatment facilities since 1956. The new plant, although capable of producing a high quality secondary effluent, did not permit discharge to the lake. Effluent disposal was accomplished by spray irrigation on land.

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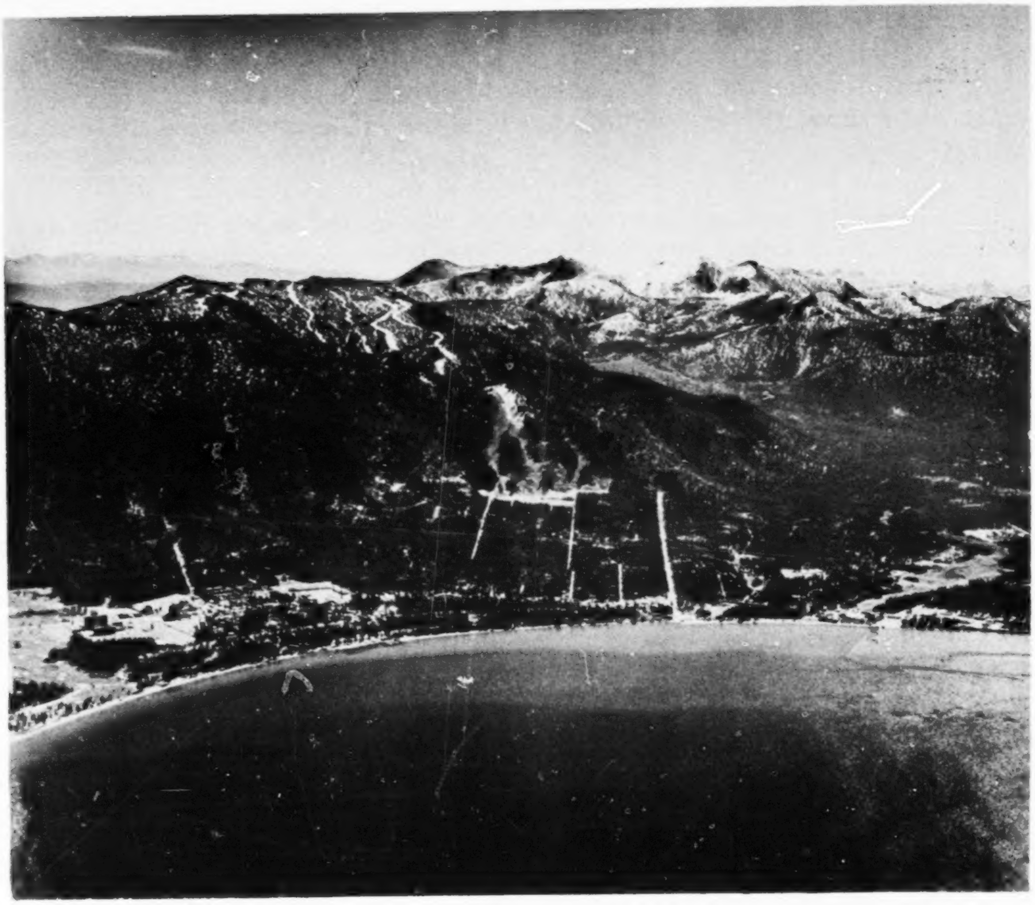

Figure 1

AERIAL VIEW OF SOUTH LAKE TAHOE

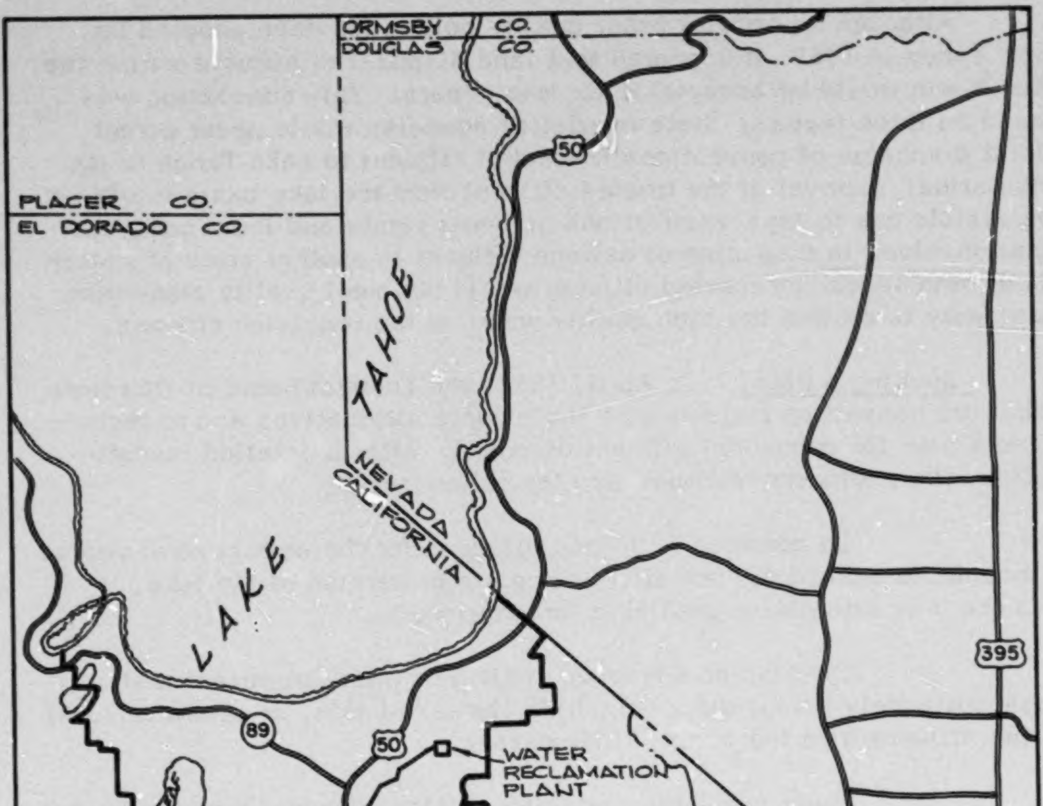
ORMSBY CO.
DOUGLAS CO.
50
PLACER CO.
EL DORADO CO.
LAKE TAHOE
NEVADA
CALIFORNIA
395
89
50
WATER RECLAMATION PLANT
FALLEN LEAF LAKE
SOUTH TAHOE PUBLIC UTILITY DISTRICT BOUNDARY
50
EFFLUENT EXPORT PIPELINE
89
EL DORADO CO.
ALPINE CO.
INDIAN CREEK RESERVOIR

FIGURE 2

SOUTH TAHOE PUBLIC UTILITY DISTRICT
SERVICE AREA

Although no official water quality policy had been adopted for Lake Tahoe in 1960, it appeared that land disposal of effluent within the lake basin would be acceptable for many years. This conclusion was based on three factors: State regulatory agencies would never permit direct discharge of conventionally treated effluent to Lake Tahoe or its tributaries; removal of the treated effluent from the lake basin would be impossible due to legal restrictions on water rights and legal complications involved in disposing of sewage effluent in another state or watershed; and secondary treated effluent would not meet quality standards necessary to protect the high quality water in the receiving streams.

Seeking A Plan. In April, 1961, the District Board of Directors asked its consulting engineers to investigate alternatives and to recommend a plan for permanent effluent disposal. After a detailed investigation, the engineers recommended the following:

To continue with land disposal for the next several years. Although the method did not afford complete protection of the lake, it was the only alternative available for interim use.

Develop an advanced method of waste treatment that might ultimately permit disposal within the lake basin, or permit removal of the effluent from the basin, if necessary.

Study available routes for effluent removal from the basin and seek an agreement that would permit disposal outside the basin.

The plan was approved and its implementation was started.

Existing land disposal areas were enlarged and a new area constructed. This was sufficient for the next several years. With the interim element completed, efforts were devoted to the final two elements of the plan, which were more time consuming and difficult.

Advanced Waste Treatment. In order for sewage effluent to be acceptable for export, it would have to be essentially of drinking water quality. If in-basin disposal were ever to be permanently allowable, maximum removal of phosphate and nitrogen would be required. Since there were few, if any, plants in the country that could meet such standards, the District decided to initiate a research program and develop a tertiary treatment process that would meet the objectives.

The consulting engineers undertook a program to develop a process utilizing chemical coagulation, filtration through multimedia filters and finally adsorption on activated carbon beds. By the end of 1963, pilot plant tests had developed to a point where the District believed that it would be possible to build and operate a tertiary treatment plant at a cost it could afford, and authorized the design of a full scale 2.5 mgd plant. The plant was constructed in 1964 and placed into service in July, 1965. The facility operated successfully; effluent quality was equal to or exceeded the expected quality and operating costs were within the predicted range.

Plant Overloaded. The completion of the tertiary plant coincided with the culmination of an unprecedented growth within the District. The existing activated sludge plant was overloaded during the summer of 1965. The 2.5 mgd plant was receiving flows up to 4 mgd. Plant performance suffered and the tertiary facility could not continuously perform adequately with poor quality secondary effluent.

By the summer of 1966, it was mandatory that the treatment plant be expanded. That fall, plans and specifications were authorized for expansion of plant capacity to 7.5 mgd. Construction began the following summer. Three major contracts were let: One provided for expansion of the primary, secondary and tertiary plants; another for construction of a new solids disposal system; and the last for construction of an experimental ammonia stripping system for nitrogen removal, which was build for only one half plant capacity, or 3.75 mgd.

The primary and secondary plant expansion consisted of adding one primary clarifier, two aeration basins, one secondary clarifier, a return sludge pump station, a chemical flocculation basin, chemical clarifier, waste activated sludge thickener, lime mud thickener and a final effluent pump station.

The tertiary plant expansion included adding four separation beds, six new activated carbon columns and new secondary effluent pumping facilities.

Solids Disposal System. Operation of the original tertiary plant posed a problem in disposing of the alum sludge produced. At first it was planned to reclaim and reuse the alum, but this proved to be not feasible. To overcome the problem, lime is used as a coagulant in the expanded plant.

In addition to the chemical sludge problem, the original plant had trouble disposing of biological sludge because its digesters and drying bed were inadequate, particularly in the winter.

For these reasons, a new solids disposal system was incorporated into the expanded plant. Biological sludge is incinerated in a six-hearth, 14.5 foot diameter furnace. Waste activated and primary sludge is dewatered to about 19 percent solids by a concurrent flow solid bowl centrifuge.

The lime sludge is reclaimed by recalcining the lime in a second multiple hearth furnace. It is thickened in a gravity flow thickener, then dewatered to about 50 percent solids by a centrifuge.

The biological furnace and the lime furnace are fired by natural gas.

The lime centrate contains most of the phosphates, which are removed by feeding the centrate to the primary clarifier and collecting this portion of the lime sludge with the biological sludge. The phosphate sludge is then incinerated along with the biological sludge, and the phosphate is disposed of as an insoluble rock phosphate in the ash.

Nitrogen Removal. Treating the secondary effluent with the high lime dose (about 300 mg/l) necessary for maximum phosphate removal and clarification raises the pH to about 11.0. At this high pH, calcium carbonate could be deposited on the piping and filter beds, so the effluent is recarbonated until the pH reaches 7.5. This is accomplished by a two-stage system utilizing CO_2, which is obtained from the furnace stack gas. Prior to lowering the pH, the lime treated effluent is pumped through a cooling tower where ammonia nitrogen is stripped from the water and released to the atmosphere as a gas. The stripping tower will remove up to 95 percent of the ammonia nitrogen.

The plant expansion, with the exception of the ammonia stripping tower, has been operating since March 31, 1968. The tower was placed in service in November 1968.

Effluent Disposal. Until 1964, the District continued to study the effluent disposal problem. State and Federal regulatory agencies were urging that export, or removal of the effluent from the Lake Tahoe Basin, be carried out since this would positively eliminate any danger to the lake from nutrient enrichment by sewage.

In November of 1963, the Governors of California and Nevada met to consider solutions to the potential pollution problem of the lake. As a result of the meeting, each State pledged its resources to carrying out a program of effluent export. The South Tahoe Public Utility District was selected as the first target, and California issued an edict telling the District to export by 1965. Unfortunately, the Governor's edict did not present a solution, but only added to the urgency of the problem.

Alternate Export Routes. The District had available at least three alternative routes for export. All routes were feasible, but each presented problems that were beyond the District's control.

The first route to be considered was a pipeline extending south from the water reclamation plant approximately 40,000 feet to discharge over Echo Summit into the South Fork of the American River. The total elevation rise would be 1,080 feet. This route offered the least annual cost and, accordingly, was recommended by the engineers.

In April of 1964, the District applied to the State of California to discharge effluent of drinking water quality into the South Fork. After a detailed investigation of the application, a public hearing was held by the Central Valley Regional Water Quality Control Board. Practically all agencies and individuals concerned protested the proposed discharge. As a result, the regional board prohibited any discharge, direct or indirect, into the South Fork of the American River at any point above Placerville. Since the town of Placerville is 45 miles downstream from Echo Summit, the first cost of the plan changed radically and the District was forced to discard the plan.

The next choice was to export to the north over Dagget Pass into Douglas County, Nevada. This route would involve a 40,000-foot pipeline and a change in elevation of about 1,030 feet. The District applied to the State of Nevada for permission to export the effluent to this location. The Nevada State Health Department indicated that a discharge of effluent of the indicated quality would be acceptable. The District then began negotiations with a counterpart in Nevada, the Douglas County Sewer Improvement District No. 1, to provide for construction of a joint export system over Dagget Pass. After several months, it appeared that negotiations of a successful joint project would not be possible due to legal and political considerations. It also appeared that the District would obtain greater State and Federal financial assistance if the project were constructed in California. Therefore, the District decided that the Dagget Pass route would be unsatisfactory.

The final choice was a route extending southerly and easterly from the water reclamation plant over Luther Pass into Alpine County, California. This route was approximately 75,000 feet long to Luther Pass, and involved an elevation change of 1,440 feet.

The District, in 1965, applied to the State of California for permission to dispose of effluent of drinking water quality, into the Hope Valley area adjacent to the West Fork of the Carson River, just over Luther Pass. The Lahontan Regional Water Quality Control Board, after an investigation and public hearing, approved the plan. The District at last thought an acceptable plan had been reached, even though the cost would be greater than the other alternates. However, the County of Alpine did not agree with the State Board. The County, under California law, had the right to establish standards and requirements for effluent disposal beyond those set by the State. Alpine County immediately passed a series of stringent ordinances establishing a water quality control policy. Among these ordinances was one prohibiting any effluent discharge into the Hope Valley region. After several months of negotiations between Alpine County, the State of California, and the District, final agreement was reached on an effluent disposal project. The agreement contained the following major points:

1) The point of discharge could not be in Hope Valley, but would be in Diamond Valley approximately 12 miles below Luther Pass.

2) The effluent must be from a tertiary treatment plant and be essentially of drinking water quality.

3) The effluent must be stored in a suitable location so that discharge will occur only during the irrigation season.

4) All effluent must be made available for irrigation use.

5) Effluent disposal would be accomplished in Alpine County and done in a manner which would allow recreational use of the impounded water, if approved by the appropriate health agencies.

6) The project, as finally designed, must be approved by all State and Federal agencies involved in water quality control of Lake Tahoe.

Even though the conditions imposed involved appreciably greater expenditures than originally anticipated, the District agreed to accept the project as approved, subject to obtaining financial aid from the State and Federal governments.

The design of the export system was authorized by the District in late 1965. The time schedule contemplated placing all elements of the system under construction during 1966, with completion of construction scheduled by the end of 1967.

The export system involved four separate major projects: The Luther Pass Pipeline, Luther Pass Pump Station, Indian Creek Pipeline and the Indian Creek Dam.

IMPLEMENTATION.

The novel scientific and engineering aspects of the South Tahoe Water Reclamation Project have been widely publicized and have received considerable attention. While these aspects are the principal subjects of this report, it must be pointed out that this project would not have been successfully completed without the unusual vision, determination, and leadership of the Board of Directors of the South Tahoe Public Utility District. A brief summary of the organization and teamwork involved in implementing the project might be valuable to other political subdivisions contemplating similar undertakings.

Figure 3 is a diagram which illustrates the mode of operation followed by the Board in coordinating and directing the efforts of various groups working on the project. The Board of Directors are the hub of the operation. Technical advice comes to them from the consulting engineers, district management, and in cooperation with State and Federal water pollution control agencies. Financial planning is a Board responsibility based on information supplied by bond counsel, the consulting engineers, and district management, and on the availability of federal grants and state loans. Public support is a direct responsibility of the Board. Public support and confidence are vital to all phases of the work, particularly to adequate financing and staffing of the project. The Board also has an important role with their legal advisors in securing the necessary political support of elected officials at the local, state, and national levels. All of these relationships are depicted in Figure 3.

PURPOSES.

Local Purposes. The local purposes of the South Tahoe Water Reclamation Project may be summarized as follows:

1. The preservation of Lake Tahoe against any possibility whatever of pollution or accelerated eutrophication from wastewater discharge.

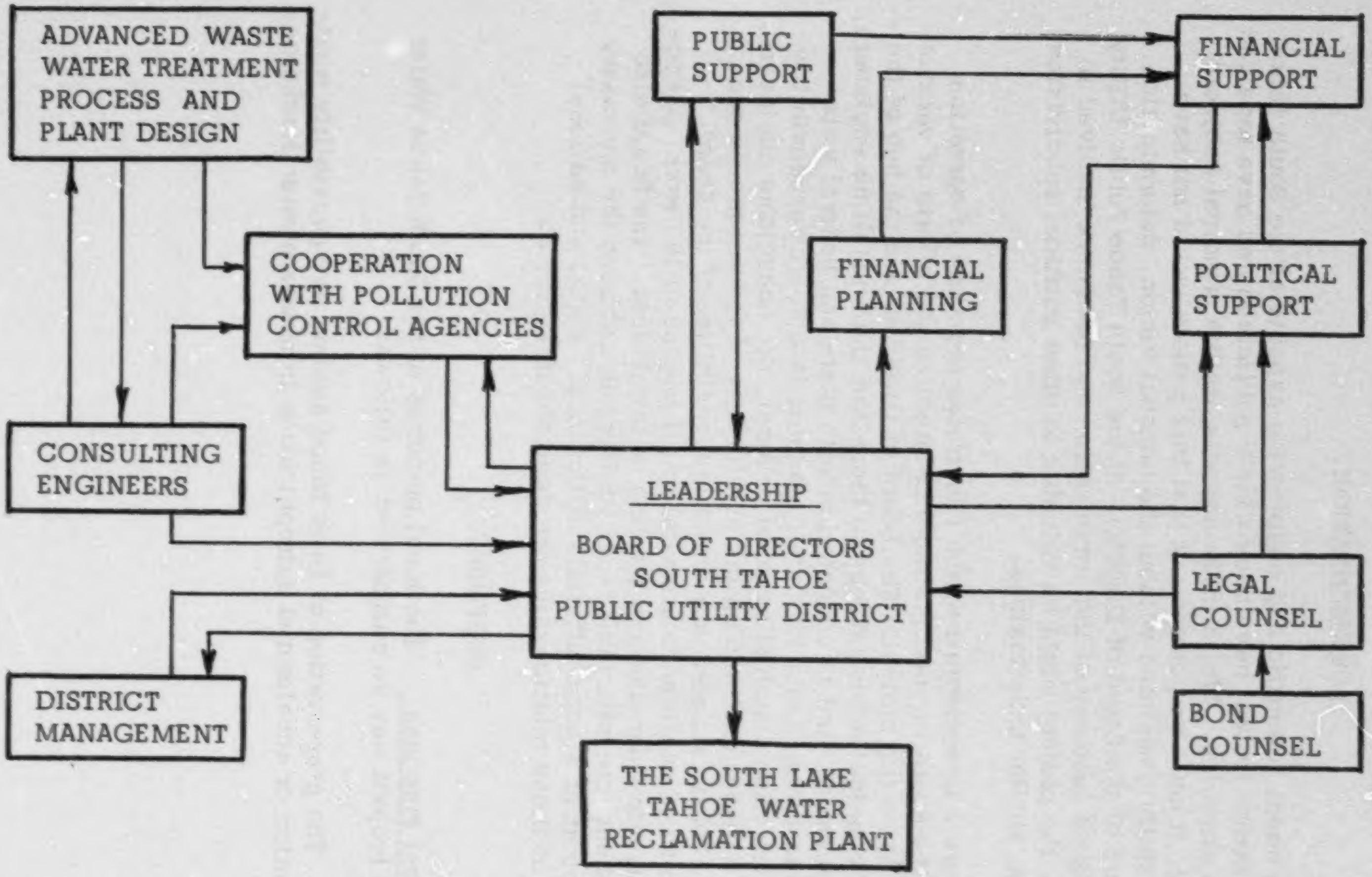
ADVANCED WASTE WATER TREATMENT PROCESS AND PLANT DESIGN
PUBLIC SUPPORT
FINANCIAL SUPPORT
COOPERATION WITH POLLUTION CONTROL AGENCIES
FINANCIAL PLANNING
POLITICAL SUPPORT
CONSULTING ENGINEERS
LEADERSHIP
BOARD OF DIRECTORS SOUTH TAHOE PUBLIC UTILITY DISTRICT
LEGAL COUNSEL
DISTRICT MANAGEMENT
BOND COUNSEL
THE SOUTH LAKE TAHOE WATER RECLAMATION PLANT

Figure 3. Organization For Project Implementation.

Figure 4 BOARD OF DIRECTORS IN SESSION

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2. Compliance with the export edict of the Nevada, California, and Federal governments.

3. Compliance with the effluent disposal standards of Alpine County which provides for water of such quality that unrestricted recreational use of stored water is permitted.

4. The development of a treatment process which will make it possible in the future to benefically reuse the reclaimed wastewater within the Tahoe Basin.

Broader Purposes. Because the South Tahoe Plant is the first full scale plant of its kind and incorporates many new treatment processes and much new equipment, and since the water it produces is so far superior in quality to conventional secondary treated effluents, there is world-wide interest in the techniques employed in the advanced treatment, the practical operational results, and the actual costs involved in construction and operation.

In view of this interest and the relation of the Tahoe Project to national water pollution control problems and goals, the Plant is designated by the Environmental Protection Agency as a National Demonstration Plant under the Clean Waters Restoration Act. Federal grants were made to aid in construction and to assist in the collection of data on the operation of the plant and the associated costs which will be useful in planning other similar works.

SECTION V

SELECTION AND INTEGRATION OF UNIT PROCESSES.

General. This Section discusses the reasoning used in selecting and sequencing the unit wastewater treatment processes which are incorporated in the South Tahoe plant.

A partial check list of factors which may influence selection and sequencing of processes follows:

1. Effluent quality required
    a. present
    b. possible future

2. Reliability and simplicity of unit processes
    a. effects of changes in flow, temperature, and applied water quality
    b. required operator skill and attention
    c. process sequence interrelationships
        (1) effects of secondary treatment upsets

3. Status of process development
    a. laboratory experiments
    b. pilot plant
    c. operating full-scale plants
        (1) design data and equipment specifications
        (2) actual operating experience
        (3) firm cost data

4. Requirements for ultimate disposal of sludge.
    a. land disposal
        (1) raw sludge
        (2) digested sludge
        (3) dewatered sludge
    b. incineration
        (1) sludge dewatering characteristics
            (a) primary sludge
            (b) waste activated sludge
            (c) chemical sludge
            (d) organic-chemical sludge mixtures

        - (2) sludge conditioning
            - (a) digestion
            - (b) heat treatment

5. Process compatibility.
    - a. optimum points for chemical application
    - b. optimum pH for each unit process
    - c. recycling of process water and waste streams
        - (1) centrate
        - (2) filtrate
        - (3) scrubber water
        - (4) filter backwash water
        - (5) carbon rinse water
        - (6) miscellaneous

6. Process flexibility.
    - a. alternate modes of operation
    - b. standby units
    - c. provisions for servicing and repair
    - d. fail safe features
        - (1) process monitoring
        - (2) restricted bypass arrangements
        - (3) alarms

7. Costs.
    - a. capital
    - b. operating
    - c. plant capacity or size of units
        - (1) powdered vs granular
        - (2) gravity vs pressure units
        - (3) materials of construction
        - (4) throwaway vs reuse of chemicals

8. Awkward process combinations. (Carrying out two or more processes simultaneously in a single treatment unit.)
    - a. general problems
        - (1) loss of individual process control and optimization
        - (2) loss of flexibility
        - (3) loss of reliability
    - b. mixing, flocculating, settling, and internal solids recycling in a single basin (solids contact basin)
    - c. chemical-primary treatment
    - d. chemical-activated sludge treatment
    - e. carbon contactor-filter
    - f. sludge incineration - lime recalcining in a single furnace

Effluent Quality Required. The first consideration in the selection of unit processes is the degree of treatment required at present and that which may be required in the future. Once the required water quality is established, then unit processes must be selected to accomplish the desired result. Obviously, for almost every situation, there are a number of combinations of unit processes which may satisfy the needs.

The requirements to be met immediately by the plant for water exported to Alpine County, Calif. as established by the Lahontan Regional Water Quality Control Board and the Board of Supervisors of Alpine County are given below.

TABLE 1

EFFLUENT QUALITY REQUIRED

	Requirements			
		Lahontan R.W.Q.C.B.		
		percent of time		
Description	Alpine Co.	50	80	100
MBAS, mg/l, less than	0.5	0.3	0.5	1.0
BOD, mg/l, less than	5	3	5	10
COD, mg/l, less than	30	20	25	50
Susp. S., mg/l, less than	2	1	2	4
Turbidity JU, less than	5	3	5	10
pH, units	6.5 to 8.5	6.5 to 9.0		
Coliform, MPN/100 ml	Adequately Disinfected	Median less than 2 Max. No. Consecutive samples greater than 23, 2		

These standards do not include any requirement for phosphorus or nitrogen removal. However, Alpine County, the recipient of the reclaimed water, included provisions in their contract with the District which clearly indicated that the receiving reservoir on Indian Creek was to be used for recreation. Since this was the case, it was decided to include provisions in the plant for the maximum degree of phosphorus removal which was feasible. The Consulting Engineers were of the opinion that phosphorus removal alone could control algal growths in the reclaimed water. This was based on "batch" algal growth tests of pilot plant effluent. It has since been verified by three years of observation of the water in Indian Creek Reservoir.

Because of the potential future beneficial reuse of the reclaimed water in the Tahoe Basin and the potential savings in electric power costs which could be realized from elimination of export pumping, it was decided to evaluate methods for nitrogen removal, since it appears that the regulatory authorities will require some degree of nitrogen removal for waters to be reused in the Basin.

Reliability. The simplicity and reliability of unit processes and sequences thereof are top priority factors. While simplicity and reliability are not synonymous, they are very closely related. The simpler the process is to operate and control, the more likely it is to operate successfully and continuously. Regardless of how highly efficient a process may be when operating at its very best under conditions rigidly controlled by experts, if it is sensitive to minor changes in flow, temperature, or applied water quality, or if it requires constant attention and adjustment, then it is not likely to operate as intended all of the time in practical plant application.

The operation of conventional secondary treatment plants is often very erratic. Settling basins are subject to upsets. The design of advanced wastewater treatment processes which follow must take this fact into account. They must be able to accept these variations in performance and still produce an effluent of uniform quality.

To secure a high degree of treatment with a high degree of reliability, it was apparent early in project planning that efficient filtration would be a necessity. Indeed, without the use of filters in advanced waste treatment flow sheets, there unquestionably will be a loss of quality in the finished water, and a serious loss of reliability in the continuity of the entire treatment process. In 1961, when this work was started, a search of the literature revealed that there was at that time no satisfactory way to filter sewage, although many attempts had been made over a period of

50 years or more to do so. Failure of these attempts resulted generally from either the rapid plugging of the filter surface or plugging over a period of time due to slime growths. Rapid sand filters, slow sand filters, and intermittent sand filters had all been used with a notable lack of success. In 1961, Raymond Pitman and Walter Conley were using in water purification at the Hanford Atomic Works in Richland, Washington a dual media (coal-sand) filter which produced a very high clarity water. This dual media filter differed from earlier versions in that it was a mixed dual media rather than a layered dual media. It utilized to a limited extent the principle of coarse-to-fine filtration. Later work by Conley, Archie Rice, and others for Microfloc, Inc. led to a major improvement in the mixed media filter for water treatment by the use of three materials, coal, sand and garnet. Proper gradation and combination of these materials results in a filter in which the pore space is uniformly graded from top to bottom of the filter and which allows storage of solids removed from the water throughout the full depth of the filter bed. The trial and adaptation of the mixed media filter to wastewater treatment at Tahoe was really the key that opened the door to practical, reliable advanced treatment. Experience in the operation of the full-scale plant has verified the fact that the filters are one of the most important parts of the entire treatment process. During normal plant operation it appears at times that filtration might be eliminated from the process with little loss in finished water quality. The full value of filtration is demonstrated when preceding processes are upset due to shock hydraulic or organic loads, equipment failure, human error, or other factors which are universally prevalent. Under these conditions filtration is indispensable. Filtration not only compensates for failures in preceding processes without interruption of treatment, but also protects processes which follow, such as carbon contact, against failure. Mixed-media filtration is the one important difference between an advanced waste treatment scheme which works and one which does not work. It should also be noted that the differences between the reliability and performance of a mixed-media filter and a dual media filter are greatest in favor of mixed-media when the poorest water is being filtered, that is, at those times when filtration is most needed.

Granular activated carbon adsorption of organics is a highly reliable process provided it follows filtration. Granular carbon can take shock hydraulic or organic loads without difficulty. However, downflow columns subject to high turbidity loadings can be troublesome. At Tahoe, upflow carbon contactors are used following mixed-media filtration which has proved to be a good arrangement. Upflow countercurrent carbon columns are also by far the most efficient from the standpoint of carbon use as will be discussed in detail later.

Following activated sludge treatment with high lime treatment is a good sequence because any biological floc carryover is usually settled out along with the lime. Following activated sludge treatment with carbon treatment equalizes variations in BOD or COD content.

Status of Process Development. The state of development of a process, particularly the number of full-scale plants from which engineering design and equipment information, actual operating results, and cost data can be obtained, has a great influence on the degree of reliability which may be expected of it. Obviously, if new approaches are not tried on a plant-scale, little progress will be made. However, engineers and clients embarking in new areas should be aware of the degree of uncertainty involved. The acceptable risk level must be determined individually for each project.

The first tests of any new treatment method are usually made in the laboratory. The next step is pilot plant operation on a continuous flow basis. Pilot plant work gives a good insight into the results to be expected from liquid processing. Unfortunately, it does not always adequately evaluate sludge problems or problems associated with recycled process streams or return solids. Only a few advanced wastewater treatment processes have been tested on a plant scale. It is only at plant scale than many engineering design problems and the practical operation problems are faced for the first time. The transformation of pilot plant data gathered by biologists, engineers, chemists, and laboratory technicians into workable engineering designs is a difficult and demanding task, and one not to be taken lightly or for granted. It is here, in the hands of the sanitary engineering designer, that the project either fails or succeeds. The success depends not only on how well he selects and combines the unit processes, but more importantly how well he selects and specifies the performance of equipment, and how well he executes the excruciating details of design. Actually, the development of this engineering design knowhow is the great gap in the application of new and better methods for wastewater treatment. There is a great backlog and wealth of information and scientific research which cannot be used until it is transformed into actual working plants. This transformation requires the design of new structures and equipment, and the provision of sufficient safety and flexibility in the design to allow for any contingencies which may not be apparent at pilot scale.

Because the problems involved in going from pilot to full scale are difficult, it is sensible to take full advantage of all prior knowledge.

There are many unknowns still remaining upon completion of pilot scale experiments which become readily discernable upon completion and operation of the full scale plant. For maximum reliability, the designers of future plants must take advantage of the prior art, modifying proven designs as necessary to meet different conditions as to size and other design variables.

The Tahoe plant designers had to rely principally on prior art in other industries, since it was the first full-scale advanced wastewater treatment plant. For example, the experience of the sugar refining industry provided some guide lines in the design of carbon contacting vessels, carbon transfer equipment, and carbon regeneration equipment and procedures. The waterworks industry provided much information on chemical treatment, recarbonation, and plant controls, and with the paper manufacturing industry supplied some data on lime recalcining and reuse. Ammonia stripping tower design relied principally on experience with cooling towers, even though there are some important functional and operational differences.

Plants which follow Tahoe will, of course, have the benefit of the Tahoe experience. In this report the difficulties as well as the successes at Tahoe will be discussed because they are of great importance to the designer. Each designer should have the privilege of making his own mistakes rather than repeating old ones.

Requirements for Ultimate Disposal of Sludge. Of major importance in process selection are the circumstances related to the handling and ultimate disposal of the sludge produced. In locations where there are available remote, large areas of land, almost any kind of sludge, wet or dry, stable or decomposing, can be, and is, disposed of by hauling or pumping to these land disposal sites. In many places this crude method for sludge disposal probably will not be tolerated indefinitely, but might suffice for the time being. Ocean disposal of sludge has long been an easy way to evade the knotty problems involved in proper sludge disposal. However, the nuisances which have been created and the damages wrought to beaches and coastal waters have aroused the public to the point where this method is now in almost universal public disfavor.

All of the more acceptable methods for sludge disposal involve dewatering of the sludge. The ease with which sludge may be dewatered is a prime factor in unit process selection. There are many alternate ways to process the liquid component of wastewater to secure the desired result at about equal costs, but there are very few ways to satisfactorily and economically dewater sludge. In sludge from certain wastewaters, dewatering of mixtures of organic-chemical sludges may be satisfactory, but care must be taken to check this out before designing a full scale plant. Favorable pilot plant test results are an important prerequisite.

Another approach which has been used successfully is to keep entirely separate all organic sludge from all chemical sludges. Then, conventional equipment used for either of these types of sludge can be installed. Pilot tests are still highly desirable, even with this approach.

Heat treatment or anaerobic digestion of organic-chemical sludges may condition these mixtures to make possible use of a wide range of dewatering equipment. Chemical conditioners may accomplish this same end, but dosages must be determined to ascertain economic feasibility.

At South Tahoe, the choices in sludge disposal were: incineration, or digestion and hauling the sludge out of the basin provided a disposal site could be found. Because of the long haul involved in sludge export, the descision to incinerate all waste organic and chemical sludges was quite easy as it was favored both by esthetics and economics. Existing sludge digestors for the original 2.5 mgd plant were utilized in the expanded plant for emergency storage of sludge. They also can be used to pretreat sludge for easier dewatering if necessary.

One of the greatest single factors favoring the tertiary sequence of treatment (in which advanced treatment follows conventional biological treatment) is the sludge handling problem. At Tahoe, mixtures of primary, waste activated, and chemical sludges proved to be prohibitively expensive to dewater, but organic sludges and chemical sludges which were kept separate dewatered readily and at low cost. This is one of the most important factors to be evaluated prior to final plant design, particularly in the decision between physical-chemical treatment and the tertiary sequence.

Process Compatibility. Another consideration in process selection is the compatibility of the process with other unit processes used in the overall treatment scheme. The possible effects of waste streams or recycled solids is very important.

The optimum pH for various unit processes is a factor which influences their compatibility, and may affect placement of processes in the plant flow sequence. There are many examples of this point. Various chemical coagulants operate best within certain pH ranges. In this case , the choice may be to adjust the pH or change the chemical used. Also it is possible to broaden the effective pH range of chemicals by use of coagulant aids, such as activated silica or polymers. Biological processes may be adversely affected by pH values above 9.3, although activated sludge cultures have great buffer capacity and it may be possible to allow the pH of the influent to activated sludge basins to exceed 9.3 so long as the pH in the aeration tank itself does not exceed this value. Phosphorus removal by lime requires raising the pH to values of 9 to 11. Ammonia stripping also is most efficient at pH values of 10.5 to 11. Calcium reaches minimum solubility at a pH near 9.3 . Carbon adsorption of organics is best at low pH values, and is very poor at pH values above 9.0. Chlorination is more effective at low pH values, at low turbidities, and in waters with low chlorine demand. Granular activated carbon adsorption is favored by good clarification of the applied water. Granular activated carbon will adsorb chlorine. With information on process interrelationships and pH effects, then, a logical process sequence for maximum reliability and effluent quality would be biological treatment followed by advanced treatment, or the so-called tertiary sequence. Although the costs may exceed those of approaches combining certain steps, there are at least three advantages to this arrangement which must be given due consideration: the pH is favorable for biological treatment; the organic sludges are kept separate from the chemical sludges which usually minimizes sludge dewatering problems; and the polyphosphates in the raw wastewater are converted to orthophosphate before chemical coagulants are applied, thus avoiding potential interference with chemical coagulation.

In considering compatibility, attention must be given to the point in the overall process at which centrate, filtrate, backwash water, scrubber water and other plant process water and recycle streams are introduced. It is wise to provide more than one point of return for some of these streams, particularly to take care of those times when certain plant units are temporarily out of service.

In the South Tahoe plant, the processes are compatible. Fortunately, sufficient flexibility was built into the plant to allow some problems in this regard to be worked out under actual plant operation. For example, an optional point of lime application to the primary tank influent was not used due to sludge dewatering problems which lime addition created. Several points of centrate (from sludge and lime centrifuges) return were provided including points to be used with certain plant units out of service. Several points for return of flue gas scrubber water were provided, but the best point for both return waters has proved to be the rapid mix. Filter backwash water is returned to the rapid mix basin, but, again, alternate points of return are provided.

As previously mentioned, at Tahoe, chemical treatment follows biological treatment which has the advantages of reducing sludge dewatering problems and taking care of biological floc carryover by chemical flocculation and settling. Also at Tahoe, once the pH of the water is raised to 11.0 with lime for phosphorus removal, the water passes through the ammonia stripping tower which requires the same high pH. Thus, one lime application serves two purposes. Two stage recarbonation, which follows, then lowers the pH to a value suitable for subsequent filtration, carbon adsorption, chlorination, and stabilization.

Process Flexibility. The capability should be provided in advanced wastewater treatment plants for as many alternate modes of operation as possible. Each basin and each piece of equipment must be taken out of service at some time for servicing or repair, and provisions must be made in the design to operate the plant under these conditions. In many cases, duplicate or standby units may be provided. The plant should include as many fail-safe features as possible, including equipment for process monitoring and alarms to signal plant failures. Bypasses around individual units are essential, but no bypass should be provided which will allow water of unacceptable quality to leave the plant.

This scheme has been followed in the design of the Tahoe plant. It is fail-safe. It has no plant bypass. It has operated for 3 years without interruption in the high quality of water produced, even though every plant unit and piece of equipment has been down at some time for service or repair. There is no reason why wastewater plants cannot be just as reliable as power generation stations or water purification plants if they are designed and operated with this intent.

Costs. Capital and operating costs are important factors in process selection. It is obviously false economy to use a process which will not do the job merely because it is cheap to install and operate. If the designers has a choice between a proven process with a high degree of reliability and a process which may be cheaper, but is of unknown or questionable reliability, then prudence is on the side of the more costly but workable process.

Plant size exerts some influence on process selection. The capacity of the Tahoe plant justifies the use of granular activated carbon with regeneration facilities, where smaller plants might use powdered carbon on a once-through,throwaway basis. The size of plant and distance to sludge disposal sites also dictates the use of equipment for recalcining and reuse of lime, while smaller plants or other locations might indicate alternate sludge handling methods or the use of chemicals other than lime.

Awkward Process Combinations. One special word of caution is appropriate with regard to the attractive and tempting possibility of combining various processes into a single process or into a single structure. By reducing the total number of structures, there are obvious savings in construction costs. Actually, this initial cost saving is usually the only advantage of combining processes, and there may be many disadvantages. The history of water and wastewater treatment is replete with failures to satisfactorily combine two or more processes. Yet, some of these mistakes are perpetuated in present day designs, and new unworkable combinations may be devised. This is not to say that some of these efforts may not end in success, but only to inject a word of caution and to point out some of the inherent weaknesses in making one process out of two or more. First of all, there is invariably a loss of control or flexibility in operation by combining two processes. A change which benefits one of the processes may interfere with or reduce the efficiency of the other. Also, in plant operation, it is much more difficult to relate cause and effect, which is necessary to make treatment adjustments, because of the greater complexity introduced by the combination. There are many specific examples which can be presented.

Upflow solids contact basins of the sludge blanket type combine the four processes of rapid mixing, flocculation, settling, and solids recycling in a single unit. They have been applied successfully to treatment of a constant flow of waters (principally well waters) which are of constant physical and chemical quality, at a considerable savings over the use of four separate operations. However, these sludge blanket basins are often not stable when operated at varying flow rates, or with waters which have significant variations in chemical composition or physical characteristics, such as temperature or organic content. It may be difficult to change the point of chemical addition in this type of basin if it becomes necessary. Also with changes in flow rate, chemical composition, or physical character of the applied water, or with the accumulation of organics in the sludge blanket, the chemical dosages required to maintain a sludge blanket of the proper density change so frequently and rapidly as to present an impossible operating condition, and the basin fails to function as a settling device. Wastewaters possess properties which make operation of sludge blanket clarifiers difficult. Some plant experiences indicate that this type of equipment can be used satisfactorily for wastewater treatment if the overflow rates are the same as for a conventional horizontal flow clarifier, and if the sludge is removed from the basin as rapidly as it reaches the bottom of the tank. Separate rapid mixing, flocculation, and settling basins with provisions for external sludge recirculation appear to be more satisfactory than solids contact basins for treatment of wastewater. Mutual interference is avoided, and complete flexibility of operation and control is afforded.

Difficulties and high costs may be involved in dewatering organic-chemical sludge mixtures in some wastewaters. Combining high lime or alum treatment with primary settling with the elimination of a separate chemical clarifier, or even going further and eliminating biological treatment, offers potential savings which are quite substantial. The possibilities certainly warrant investigation in each instance to see of there is a sludge dewatering problem, and, if so, if there is an economical solution to it. This should be done on a pilot plant scale before undertaking the building of a full scale plant.

Combining chemical treatment with activated sludge treatment for phosphorus removal also presents some practical difficulties at full plant scale which should not be overlooked, even though there may be ways to solve the problems. Additon of lime or alum to aeration tanks secures excellent phosphorus removal. The difficulty is that the inert chemical sludge accumulates and selectively displaces the culture of activated sludge organisms over a period of a few weeks, and normal biological treatment ceases. Because of the differences in specific gravity between the chemical and biological sludges it may be possible to separate them and return or waste them as necessary to control the process, but this remains to be demonstrated on a plant scale.

Combination downflow carbon contactor-filters are used successfully in water treatment plant practice where there are low suspended solids in the applied water. However, the carbon contactor-filter is a surface filter, and not an in-depth filter, and as such is subject to the same limitations as any other surface filter in filtering wastewater. The use of granular carbon as a contactor-filter has all of the same disadvantages of other surface filters plus the additional one of being a much deeper bed, which is more difficult to properly clean by backwashing than a shallower bed. Also, the use of carbon as a filter to remove suspended and colloidal matter from the water is likely to blind the carbon pore openings and require removal of the carbon from the bed before its full adsorptive capacity is exhausted.

Flocculation and settling of organics and lime sludge in the same basin poses another problem if the lime is to be recalcined and reused. Calcium carbonate has been recalcined and organics incinerated successfully in a single furnace. However, this means that the recalcined lime contains considerable inert ash. There are two choices, the ash can be recycled with the recalcined lime, or some means can be devised to separate the lime from the ash. If the ash is recycled with the lime it becomes wet again and there are extra costs for fuel for repeated drying of the ash on subsequent cycles. It is necessary to waste about 25 to 35 percent of the recalcined lime on each cycle of use to rid the system of phosphates, and a similar portion of the recycled ash would automatically be wasted in the same operation. This would be an acceptable way to operate, and the decision as to whether to settle and incinerate organics and chemical sludge together or separately can be resolved by a rigid cost analysis including, of course, all capital and operating costs. Whether to attempt to separate the ash from the reclaimed lime as opposed to recycling the ash with the lime also is strictly a matter of comparative costs, assuming that either a wet separation or a dry separation can be made successfully.

These examples should serve to illustrate some possible problems which may be encountered when attempting to combine two or more unit processes into a single unit. Combining processes usually complicates operation and control and decreases reliability, while the designer should be seeking to simplify operation and control, provide maximum flexibility of operation, and insure greater reliability. There is no point in combining two perfectly good unit processes into one poor one. Because of the potential savings, efforts to determine workable combinations should certainly continue.

In the South Tahoe plant separate basins are provided for chemical mixing, flocculation, and clarification. External sludge recirculation is provided. Separate filters and carbon contactors are used. These arrangements have proved to be eminently satisfactory.

Storage. One way to reduce capital costs for construction of advanced wastewater treatment plants is to introduce storage of wastewater at some point in the system. This should be done after the water has received sufficient treatment so as not to create a nuisance on standing. Sufficient storage should be provided to allow the sections of the plant which follow the storage to operate at the average rate for the design maximum day rather than at the peak hourly rate for the maximum day. A rough rule of thumb for separate sanitary sewer systems is to build at least 1.5 to 2.0 million gallons of storage for each 10 mgd of plant capacity. The exact requirements vary for each individual collection system, and the rule of the thumb does not apply to systems receiving sanitary sewage plus storm water.

At Tahoe, about 2 mg of storage is provided just after secondary recarbonation and just ahead of filtration. This provides storage for backwashing water and equalizes flow through the filters and carbon columns which are designed to handle maximum daily rather than peak hourly flows.

Disinfection. Virus and bacterial removal are important considerations in wastewater treatment. At Tahoe, removal of these organisms is virtually complete before chlorination so that the high quality water, which has a very low chlorine demand, is ideal for complete disinfection by chlorination.

Summary. Since 1967, when the Tahoe treatment process was finalized, the unit processes and their sequence have been under constant observation and review both in the light of plant operating experience and new developments in the field at other locations. There is a constant search for improving the process. However, despite this concern and continuous reevaluation and reexamination, under the conditions at Tahoe, this flow sheet still appears to be the best. It must be pointed out that other conditions will require other solutions to optimize results and costs to accomplish different treatment objectives. In general, it is believed that these solutions to be used under other conditions will consist of eliminating certain steps which are unnecessary rather than in combining them or in changing the sequence of unit processes.

SECTION VI

THE TAHOE PROCESS FOR WASTEWATER RECLAMATION

Water Reclamation Plant. The South Tahoe water reclamation plant is the most advanced full-scale wastewater treatment plant in the world, although other similar plants are now under construction in other places.

Treatment of wastewater consists of two basic parts, liquid processing and solids handling. The first two steps of liquid processing are the conventional ones of primary, or solids separation, and secondary, or biological oxidation. In addition, the advanced treatment provides chemical treatment and phosphate removal, nitrogen removal, mixed-media filtration, activated carbon adsorption, and disinfection.

The solids handling system provides for incineration of biological sludge, regeneration and reuse of granular activated carbon, and recalcining and reuse of lime, all by means of multiple hearth furnaces. The furnaces are equipped with scrubbers and after-burners to prevent air pollution.

A detailed description of the treatment plant processes will be given in the normal order which they occur in flow through the plant, first for the liquid processing and then for the solids handling.

Figure 5 is a schematic flow and process diagram.

Liquid Processing. All wastewater is pumped to the reclamation plant. Plant influent may be prechlorinated for odor control. The raw wastewater is then passed through a barminutor which screens and shreds the coarse solids, then through Parshall flumes which measure the plant inflow.

The water then passes to either or both of two primary settling tanks where the liquids and solids are separated by sedimentation. In addition to the raw wastewater, the primary tanks may also receive the overflow from the lime mud thickener, and the centrate from the lime centrifuge or the sludge centrifuge. If desired, lime or polymer may be

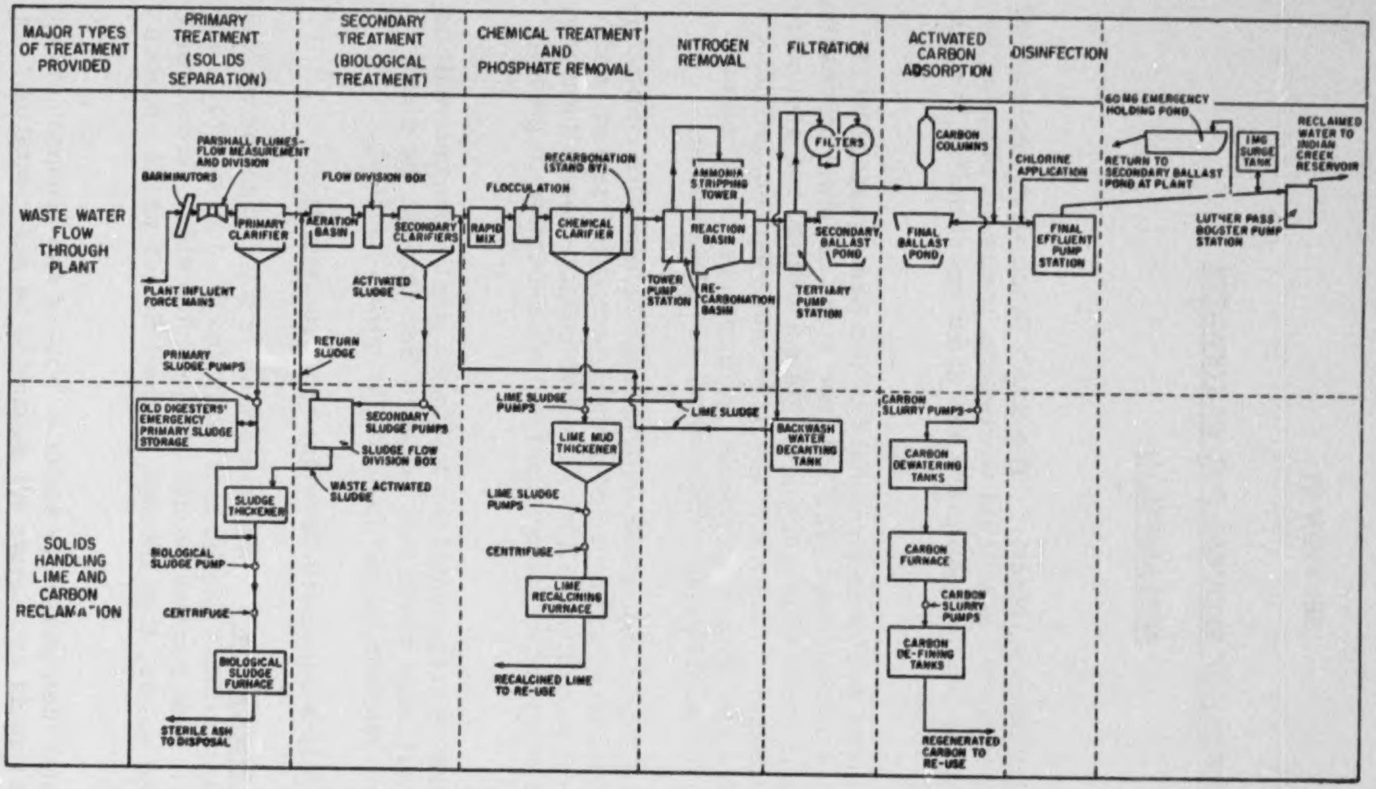
MAJOR TYPES OF TREATMENT PROVIDED
PRIMARY TREATMENT (SOLIDS SEPARATION)
SECONDARY TREATMENT (BIOLOGICAL TREATMENT)
CHEMICAL TREATMENT AND PHOSPHATE REMOVAL
NITROGEN REMOVAL
FILTRATION
ACTIVATED CARBON ADSORPTION
DISINFECTION
WASTE WATER FLOW THROUGH PLANT
SOLIDS HANDLING LIME AND CARBON RECLAMATION
BARMINUTORS
PARSHALL FLUMES-FLOW MEASUREMENT AND DIVISION
PRIMARY CLARIFIER
PLANT INFLUENT FORCE MAINS
PRIMARY SLUDGE PUMPS
OLD DIGESTERS' EMERGENCY PRIMARY SLUDGE STORAGE
SLUDGE THICKENER
BIOLOGICAL SLUDGE PUMP
CENTRIFUGE
BIOLOGICAL SLUDGE FURNACE
STERILE ASH TO DISPOSAL
AERATION BASIN
FLOW DIVISION BOX
SECONDARY CLARIFIERS
ACTIVATED SLUDGE
RETURN SLUDGE
SECONDARY SLUDGE PUMPS
SLUDGE FLOW DIVISION BOX
WASTE ACTIVATED SLUDGE
RAPID MIX
FLOCCULATION
RECARBONATION (STAND BY)
CHEMICAL CLARIFIER
LIME SLUDGE PUMPS
LIME MUD THICKENER
LIME SLUDGE PUMPS
CENTRIFUGE
LIME RECALCINING FURNACE
RECALCINED LIME TO RE-USE
AMMONIA STRIPPING TOWER
REACTION BASIN
TOWER PUMP STATION
RE-CARBONATION BASIN
LIME SLUDGE
FILTERS
SECONDARY BALLAST POND
TERTIARY PUMP STATION
BACKWASH WATER DECANTING TANK
CARBON COLUMNS
FINAL BALLAST POND
CARBON SLURRY PUMPS
CARBON DEWATERING TANKS
CARBON FURNACE
CARBON SLURRY PUMPS
CARBON DE-FINING TANKS
REGENERATED CARBON TO RE-USE
CHLORINE APPLICATION
FINAL EFFLUENT PUMP STATION
60 MG EMERGENCY HOLDING POND
RETURN TO SECONDARY BALLAST POND AT PLANT
1MG SURGE TANK
RECLAIMED WATER TO INDIAN CREEK RESERVOIR
LUTHER PASS BOOSTER PUMP STATION

FIGURE 5

SCHEMATIC FLOW AND PROCESS DIAGRAM

added ahead of the primary tanks. One of the primary tanks is a rectangular basin, and the other is a circular basin. Both are equipped with mechanical collectors for continuous sludge removal.

The next step in the process is secondary treatment or biological oxidation. One-third of the plant capacity utilizes the conventional plug-flow activated sludge process with diffused air. The other two-thirds of the secondary treatment capacity is provided by a complete mix system using a combination of diffused air and mechanical mixing, or surface aeration. Secondary settling takes place in either of two circular basins, each of which has its own sludge recirculation pump station. Chlorine may be added to the secondary settling basin influent for control of sludge bulking as necessary.

Secondary settling is the end of the processing in conventional treatment plants, so that the additional treatment provided beyond this point is all in the nature of advanced waste treatment.

The secondary effluent together with waste filter backwash water enters a rapid mix basin where violent mechanical stirring occurs, and where lime is added to pH=11+, which corresponds to a dosage of about 400 mg/l of lime. Next comes a period of slow mixing and flocculation by air agitation. Following this, a polymer is added, usually in the amount of about 0.1 mg/l, as the flocculated high-pH water flows to the chemical clarifier. The chemical clarifier, a circular basin, separates the liquid from the rather large quantities of lime sludge.

Overflow water from the chemical clarifiers flows by gravity to a sump where either of two pumps lifts it to the top of the nitrogen removal tower, the first tower of its kind used in a municipal wastewater plant. The tower has a nominal capacity of 3.75 mgd (one-half plant capacity), and is the only part of the full-scale plant which is still considered to be experimental in nature. Water pumped to the tower has pH=11±, indicating that the ammonia is virtually all present as dissolved gas, rather than as ammonium ion in solution. Large quantities of air must be circulated through the tower for best efficiency, so that an open packing must be used in the tower to minimize head losses and power requirements for the circulating fan.

The water is distributed uniformly from a horizontal tray across the top of the packing, which is made of treated hemlock slats spaced at 1.5 in. vertically and 2 in. horizontally. As the water strikes a slat, droplets are formed. Surface film thickness in the droplets is at a minimum as they are forming, and this favors the escape of ammonia gas from the droplet. By circulating a great amount of air through the tower, the air surrounding the droplet is kept at a low ammonia concentration, promoting a maximum transfer of ammonia from the water to the air. Once droplets are fully formed, very little further transfer of ammonia takes place, so the droplets are coalesced on top of the next slat below and new droplets are formed as the water falls off the slat, allowing further escape of the ammonia. This process is repeated about 240 times in one pass through the 24-ft-high tower.

Air in the tower flows across the descending droplets. The air enters through the side louvers and travels horizontally to a central plenum, where it is discharged vertically upward through a fan that has a maximum capacity of 700,000 cfm. Tower loading rates are about 2.9 gpm of water per square foot, and about 390 cfm of air per gallon of wastewater. The efficiency of the tower in removing ammonia will vary from 30 to 98 percent, depending principally upon air and water temperatures and to a lesser extent upon hydraulic loading and air supply.

From the catch basin beneath the nitrogen removal tower, the tower effluent passes over a weir for flow measurement, and then into another basin beneath the tower, which contains three sections. The first section is the primary recarbonation basin. Here, carbon dioxide gas, supplied by compressing stack gasses in the incinerator building, is dissolved in the water to lower the pH from 11 to 9.6. The recarbonated water is then held in a contact basin for 30 minutes or more to allow complete formation and some settlement of calcium carbonate. This basin is equipped with equipment for continuous sludge removal. The third section of the basin is the secondary recarbonation chamber, where the pH is reduced from 9.6 to any desired level, usually 7.5, by further addition of carbon dioxide.

The recarbonated water then flows through two ballast ponds in series. The ballast ponds are used to store water for backwashing the mixed-media filters, and to reduce peak flows to the filters and carbon columns.

Water is pumped from the ballast ponds to the filters and carbon columns. Ordinarily about 5 mg/l of alum are added to the filter influent water. Three pairs of mixed-media filter beds, developed especially for filtering waste water, handle the plant flow.

The mixed-media bed, with pores graded coarse to fine in the direction of flow, is composed of coarse coal, with a specific gravity of 1.4; medium-sized sand, with a specific gravity of 2.65; and fine garnet, with a specific gravity of 4.5. A properly graded bed made of these materials provides an almost ideal coarse-to-fine filter. Because of the different specific gravities of the three materials, the particles retain their desired position in the depth of the bed during backwashing. The fine filter media is supported on a conventional bed of graded gravel, to which has been added an important new feature, a 3-in. layer of 16-mesh garnet. This extremely heavy material (specific 4.5) positively prevents any movement of the gravel bed below, and also prevents any penetration of the fine garnet above into the gravel supporting bed. The filters are equipped with rotary surface washers, and rotation indicator lights. Good surface wash is essential to proper operation of the coarse-to-fine filters because of the large quantities of particulates removed from the water and stored throughout the depth of the bed.

Each pair of beds comprises a filter unit, and they operate in series both during filtration and backwash. A total depth of 6 ft of fine media is provided in each pair of beds. With coarse-to-fine filters, the length of filter run is almost directly proportional to the depth of fine media, so that the length of run for the two beds in series is about double that for a single bed. By backwashing the two beds in series, about half as much backwash water is discharged to the decant tank and then returned at a slow rate to the rapid-mix basin for reprocessing.

When a pair of filters is plugged or no longer produces a high quality effluent, it is automatically taken off the line, backwashed, filtered-to-waste, and restored to service. This is all done automatically and monitored through a control panel located in the filter building.

The filtered water next flows under pressure to the eight carbon columns, which operate in parallel. Each column is 12 ft in diameter by 24 ft high, and contains about 22 tons of 8 X 30 mesh granular activated carbon. Flow in the columns is of the moving bed, countercurrent type - that is, water flows from the bottom to top of the column, while movement of the carbon is down, the fresh carbon being added at the top and the spent carbon removed at the bottom. This system permits frequent removal and corresponding addition of carbon for maximum operating efficiency.

The water is in contact with the carbon for a period of 15 to 25 minutes, during which the adsorption of organics by the carbon takes place. The carbon column effluent is colorless, odorless, low in organics, and sparkling clear.

The high quality of the water following complete treatment vastly improves the efficiency of chlorination, the final step in the liquid processing. As compared to chlorination of ordinary secondary effluent, the chlorination of the reclaimed water at South Tahoe is many times more effective, as virtually all of the chlorine-demanding materials, except ammonia, present in the secondary effluent have been removed. With rapid violent mixing at the point of chlorine application, good disinfection can be accomplished in the presence of ammonia. One explanation offered is that chlorine reacts more rapidly with bacteria and viruses than with ammonia.

Solids Handling System. As mentioned previously, all solid plant wastes are processed in multiple hearth furnaces. The biological and waste chemical sludges are incinerated, the lime mud is recalcined and reused in the process, and the spent granular carbon is regenerated and reused.

The materials to be incinerated include primary and waste activated sludge, waste chemical sludge, screenings, skimmings, and the centrates from the lime and sludge centrifuges.

A mixture of all of these materials is pumped to the sludge centrifuge, which operates at about 1,600 rpm, where a polymer is added and the sludge is partially dewatered to a solids content of about 19 percent in the cake. The cake is conveyed by belt to a multiple hearth furnace; the fuel is natural gas. The furnace is operated at about 1,600 °F and reduces the sludge to an insoluble sterile ash, which may be disposed of on the plant grounds. The furnace stack gas is cooled to 110°F and scrubbed. There is no odor, smoke or steam plume, and the discharges meet all air pollution codes. When the sludge dewatering or incineration equipment is out of service, the old sludge digesters may be used for sludge storage.

Handling of the spent lime mud is similar to that just described for biological sludge. Lime sludge from the chemical clarifier is pumped to a sludge thickener which thickens the sludge to about 8 percent solids. The thickened sludge is then pumped to a centrifuge for further dewatering at 1,600 rpm. The cake contains about 40 percent solids. The lime is recalcined at about 1,850°F to a calcium oxide content of about 50 to 80 percent. Again the stack gas is cooled and scrubbed so that there is no air pollution. Only about 75 percent of the lime sludge is recalcined and reused. The other 25 percent is wasted, mostly hydroxyapatite, in the centrate to the primary clarifier and thence to the sludge furnace, or directly to the sludge furnace. Alternately, the centrate from the lime centrifuge can be dewatered in a second centrifuge and the cake incinerated in the sludge furnace.

The recalcined lime is conveyed pneumatically to a storage bin, and then reused in the process. Makeup lime is unloaded from trucks pneumatically and stored in a separate bin. Separate gravimetric feeders and slakers are provided for the recalcined and makeup lime. Many of the furnace operations are controlled from a panel on the main floor of the incineration building.

The carbon regeneration equipment is located in the filter building. After the carbon becomes saturated with materials removed from the wastewater, it loses its capacity to absorb certain organics, and must be regenerated. Originally in 1965, a break-through of MBAS (or detergents) was the indicator that regeneration was needed. With the advent of the soft detergents, a high COD content in the carbon column effluent has become the indicator. In regeneration a carbon column is pressurized and the carbon slurry is drawn off the bottom of the column to one of the dewatering bins. Here the free moisture drains off in about 10 minutes, leaving carbon with a moisture content of about 40 percent, which is suitable for introduction of carbon to the furnace. Spent carbon is fed to the furnace at a controlled rate by a screw conveyor equipped with variable speed drive. The carbon regeneration furnace is operated at about 1,700°F in a limited oxygen atmosphere with the addition of steam. The rate of feed to the furnace and the hearth temperatures are controlled by the apparent density of the regenerated carbon, which is held at 0.48 to 0.49. As a check on regeneration efficiency, iodine numbers (a relative measure of adsorptive capacity) are run on carbon samples in the laboratory. The carbon is regenerated to full virgin activity with an attrition loss that is about 8 percent per cycle. The regenerated carbon is cooled in a quench tank, pumped by a diaphragm slurry pump to wash tanks, washed to remove carbon fines, and then returned to the top of the carbon column.

SECTION VII

PLANT DESIGN DATA

The principal design criteria for the South Tahoe Water Reclamation Plant are tabulated below.

Item	Amount	
Plant design average flow	7.5	mgd
Peak flow rate (except as noted below)	15.0	mgd
Peak flow rate (filters and carbon columns)	8.2	mgd
Maximum hydraulic rate	20.0	mgd
Plant design BOD (summer)	325	mg/l
Plant design BOD (winter)	250	mg/l
Plant suspended solids (summer)	200	mg/l
Plant suspended solids (winter)	150	mg/l
Water temperature (summer)	17°	C
Atmospheric pressure (elevation 6,300 ft)	11.6	psi
Primary clarifier No. 1		
Surface area	2,350	sf
Flow	2.7	mgd
Overflow rate	1,150	gpd/sf
Primary clarifier No. 2		
Surface area	7,850	sf
Flow	4.8	mgd
Overflow rate	610	gpd/sf
Aeration basins 1,2, and 3, plug flow		
Flow	2.7	mgd
Volume	115,000	cf
Detention (without recycle)	7.5	hrs
BOD loading	50 lbs/1,000	cf

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Item	Amount	
Aeration basins 4 and 5, complete mix		
Flow	4.8	mgd
Volume	137,000	cf
Detention (without recycle)	5	hrs
BOD loading	70 lbs/1,000	cf
Secondary clarifier No. 1		
Surface area	2,830	sf
Overflow rate	900	gpd/sf
Secondary clarifier No. 2		
Surface area	7,850	sf
Overflow rate	700	gpd/sf
Sludge recirculation		
Secondary clarifier No. 1	1,380	gpm
Secondary clarifier No. 2	3,840	gpm
Sludge		
Primary, dry solids	8,130	lbs/day
Waste activated, dry solids	9,760	lbs/day
Rapid mixer, mechanical	30	seconds
Chemical feed equipment		
Gravimetric lime feeders and slakers		
Recalcined lime	1,500	lbs/hr
Makeup lime	1,500	lbs/hr
Liquid alum feeders		
Two, each	50	gph
Polymer solution feed pumps		
Four, each	50	gph
Chemical storage		
Recalcined lime	35	tons
Makeup lime	35	tons
Liquid alum	10,000	gals

Item	Amount
Flocculation chamber	
Air Mix	4.5 mins
Chemical clarifier	
Flow	7.5 mgd
Surface area	7,850 sf
Overflow rate	950 gpd/sf
Lime sludge pumps	
Centrifugal	450 gpm
Progressive cavity displacement	100 gpm
Lime mud thickener	
Flow	450 gpm
Surface overflow rate	1,000 gpd/sf
Surface dry solids loading	200 lbs/day/sf
Thickened sludge solids	8-20 %
Ammonia stripping tower, cross-flow	
Wastewater flow	3.75 mgd
Fill (packing):	
Area	900 sf
Height	24 ft
Splash bars	3/8" x 1½"
Spacing, between centerlines	
Vertical	1.33"
Horizontal	2"
Recarbonation, two-stage with intermediate settling	
Flow	7.5 mgd
Carbon dioxide compressors	
No. 1	500 cfm
No. 2	1,000 cfm
No. 3	950 cfm
Reaction basin	
Detention	30 mins
Surface overflow rate	2,400 gpd/sf
Ballast pond capacity	
No. 1	1.0 mg
No. 2	1.5 mg

Item	Amount
Pumps to tertiary plant	
No. 1	1,900 gpm
No. 2	3,800 gpm
No. 3	4,200 gpm
Surface wash booster	500 gpm
Mixed media filters	
Flow	8.2 mgd
Units, 3 sets of 2 series beds	
Hydraulic loading	5 gpm/sf
Backwash rate	15 gpm/sf
Area each bed	380 sf
Surface wash flow	0.6 gpm/sf
Waste backwash water receiving tank	
Capacity	80,000 gals
Carbon columns (8), upflow countercurrent	
Flow	8.2 mgd
Carbon volume, each column	1,810 cf
Carbon depth, effective	14 ft
Contact time	17 min
Hydraulic loading	6.5 gpm/sf
Chlorination equipment	
Three feeders, each	2,000 lbs/day
Carbon regeneration furnace, 6-hearth, 54-inch diameter, gas-fired	
Capacity, dry carbon	6,000 lbs/day
Sludge dewatering equipment, concurrent flow centrifuges, 24" x 60"	
Organic sludge	
Number	2
Capacity, each, dry solids	450 lbs/hr
Lime sludge	
Number	1
Capacity	1,650 lbs/hr

Item	Amount
Sludge incineration furnace, 6-hearth 14'-3" diameter, gas-fired Capacity, dry solids	900 lbs/hr
Lime recalcining furnace, 6-hearth 14'-3" diameter, gas-fired Capacity, dry CaO	10 tons/day

SECTION VIII

EXPORT SYSTEM

Description. The export system involved four separate major projects: The Luther Pass Pipeline, Luther Pass Pump Station, Indian Creek Pipeline and the Indian Creek Dam.

The Luther Pass Pipeline extends approximately 77,000 feet from the treatment plant at South Lake Tahoe to Luther Pass. This line has an initial design capacity of 7.5 mgd and is designed for expansion to 15 mgd when necessary. The line is 55,000 feet long between the water reclamation plant pump station and the Luther Pass Pump Station. This section consists of 24-inch-diameter pipe and has a maximum operating pressure of 170 psi at design flow and a static head of 265 feet.

The section from the Luther Pass Pump Station to Luther Pass is about 22,000 feet long; the first 10,000 feet is a 20-inch line, and the remainder, 24-inch. The pipeline leaving the station rises rapidly from elevation 6,500 to elevation 7,400 in a horizontal distance of 6,500 feet. The pipeline continues to rise, climbing from elevation 7,400 to elevation 7,700 in the next 6,000 feet. The last portion of the line is quite flat, rising from elevation 7,700 to elevation 7,735 at Luther Pass in a distance of 10,000 feet. Construction of the Luther Pass Pipeline began in September, 1966 and was completed in December, 1967.

The Luther Pass Pump Station is located near the end of the Upper Truckee Valley at the bottom of Luther Pass. It is the main export station and lifts the water from elevation 6,500 to elevation 7,735 at the summit of Luther Pass, a static head of 1,235 feet. The total operating head at design flow is 1,320 feet. The station has an initial design capacity of 7.5 mgd, and can be expanded to an ultimate capacity of 15 mgd. Three pumps were initially installed; one 1,000 hp and two 700 hp. The pumps are horizontal, double volute, multi-staged, centrifugal type, driven by constant speed electric motors - the motors are 3,500 rpm, 2,300 volts. The pump operation is automatically controlled by water level in an adjacent 1,000,000-gallon steel reservoir. The control system provides for staged pump operation with one or more pumps running,

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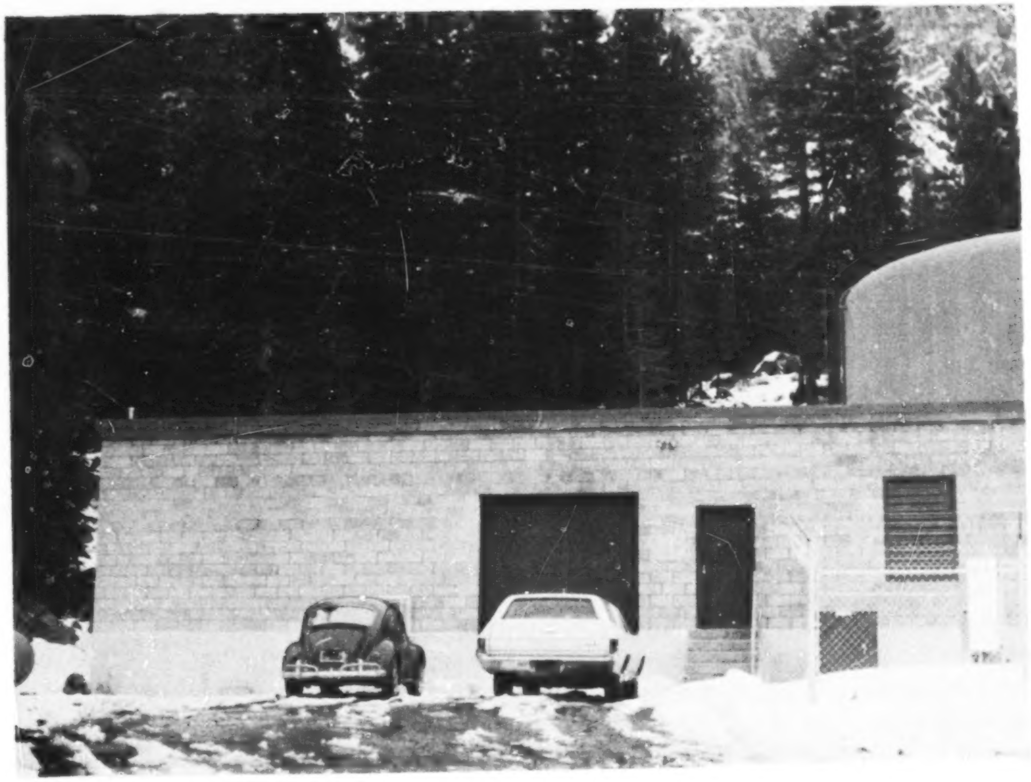

Figure 6

LUTHER PASS PUMP STATION

depending on the incoming flow rate. The station is designed for automatic operation, incorporating a variety of alarms and automatic shutdown features, all of which are transmitted to the water reclamation plant.

The pumps are normally started, or stopped, through pump control valves designed to provide a controlled opening and closing time to eliminate pressure surges in normal operation. In the event of power failure or any circumstance involving pump failures, pressure surges of dangerous magnitude will be prevented by surge suppressor valves located upstream of the pump control valves. In the event of power failures, the pump control valves close immediately, due to check valve action; the surge suppressors open within a few seconds and allow the pipeline to discharge to atmosphere. The surge suppressors then close slowly through a timed operating cycle, and allow the water column to be brought to rest without pressure surges. Construction on the station started in September, 1966 and was completed in January, 1968.

The Indian Creek Pipeline begins at the summit of Luther Pass and extends approximately 62,000 feet easterly into the Diamond Valley area of Alpine County. This line has a design capacity of 15 mgd and consists of 18-inch and 21-inch cement-mortar-lined steel pipe. The line is designed for gravity flow, and the average slope exceeds 5 percent. The elevation at the beginning is 7,735, and at the terminus, 5,600. Construction began in June of 1967 and was completed in December 1967.

The final project in the export system is the Indian Creek Dam. This dam is located on a normally dry tributary of Indian Creek. This project actually contains two dams. The main dam extends 67 feet above stream bed with a crest length of 1,440 feet. In addition, there is a saddle dam approximately 20 feet high and 800 feet long. Both dams are of earth and rock-fill construction, utilizing native materials from within reservoir site. The dam creates a reservoir with a maximum capacity of 3,225 acre-feet at a water surface elevation of 5,600 feet with a surface area of 165 acres. The reservoir will provide storage of the reclaimed water which will be disposed of on downstream ranch lands during the irrigation season. The irrigation function is a definite asset for this area of Alpine County. In addition to the irrigation benefits, a rainbow trout fishery has been established in the Reservoir. The State regulatory agencies, including the California State Department of Public Health, have approved the use of the Reservoir for all water contact sports and fishing. Construction of the dam and reservoir started in July, 1967, and the project was completed in December, 1967. Filling of the Reservoir began in March 1968. It was opened for trout fishing on May 2, 1970. See Figure 7.

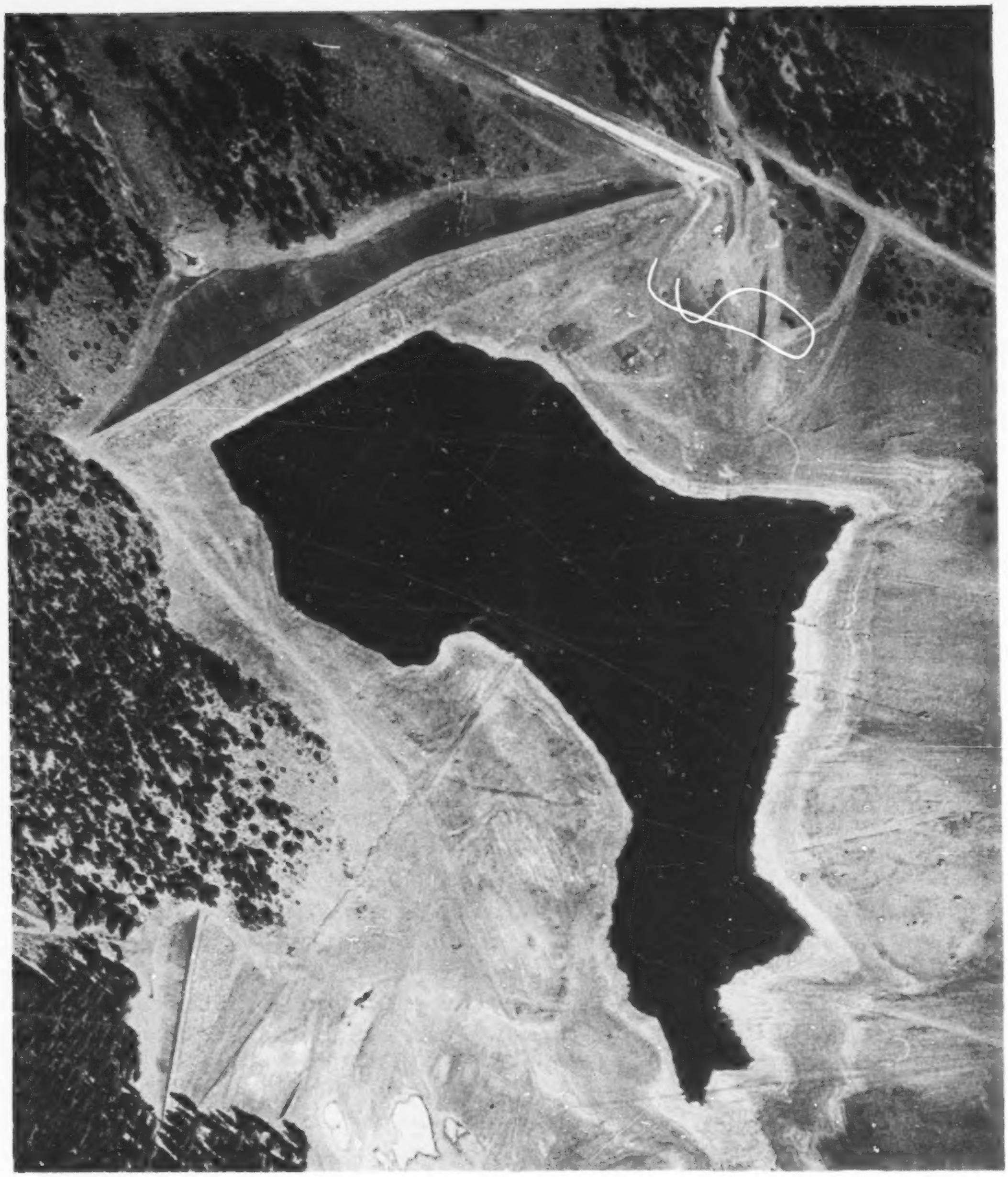

Figure 7

INDIAN CREEK RESERVOIR
DURING INITIAL FILLING

NOT REPRODUCIBLE

These four projects represent the backbone of the reclaimed water export system. The system is unique in that it transports water sufficiently pure, so that it can be directly reused, out of the Tahoe Basin, over mountains requiring a 1,600-foot pump lift to a point 27 miles from the treatment plant for final disposal.

SECTION IX

OPERATOR TRAINING

Introduction. The successful performance of any wastewater treatment plant depends largely upon the training and ability of the men who are responsible for its operation, and upon the effort and attention which they devote to their duties. Good performance is also dependent upon the consulting engineer to design a plant which is capable of producing a finished effluent which satisfies all requirements for discharge or reuse, including those minimum criteria established by local, state, and federal regulatory agencies. Further, the owner or operating agency must provide sufficient funds for proper operation and maintenance of the treatment facilities. Once these preliminaries have been accomplished by the engineer and owner, then the success or failure of the plant in fulfilling its objectives is in the hands of the operating staff. The operators are responsible for the quality of the treated wastewater and its effects upon the receiving natural waters. They are also responsible for the service life of the plant and equipment, costs for operation and maintenance, appearance of the buildings and grounds, keeping of adequate records, and for establishing and maintaining good public relations.

Good plant operation requires not only the ability to operate, maintain, and repair mechanical equipment, but also a working knowledge of hydraulics, bacteriology, and chemistry. Except in very large wastewater treatment plants, it is unusual to find a graduate engineer, chemist or bacteriologist involved in operations. Most wastewater treatment plant operators must be hired locally and trained on the job. The engineer and owner must recognize the benefits which accrue from good operation and provide adequately financed and supervised on-the-job training. This training must start even before the plant is first placed into operation and must continue as required in order to train new employees and to inform experienced operators of new developments.

South Tahoe Training Program. Prior to startup of the 7.5 mgd advanced waste treatment plant, an on-the-job operator training program was conducted. This course consisted of 33 two-hour sessions which were held during a seven week period. Duplicate sessions were held,

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one from 7 to 9 A.M. and the other from 4 to 6 P.M., in order to accommodate operators from all shifts. Operators were paid for their time in class. This should be done to indicate to the operators that management recognizes that adequate training is important. There is no substitute for on-the-job training for this work. It can be supplemented by academic training or short courses, but some on-the-job orientation is absolutely necessary. The instructors for the training course included the district manager, and representatives of the consulting engineers, construction contractors, and major material suppliers. All of these people were also paid for their time spent in the school.

The main text for the course was an Operations Manual which was prepared by the consulting engineers and paid for by the District. This manual contained more than 200 pages of material including: a discussion of the purposes of treatment and the plant processes provided to accomplish the desired result; complete illustrations of plant flow patterns under normal operating conditions, alternate flow patterns, and flow routings for emergency situations; complete description of each part of the plant process and the equipment provided for carrying it out; a discussion of all methods for control of plant operation including sampling and laboratory tests; and forms for reporting analyses, recording flow and operating information, and summarizing all plant data on a monthly or weekly basis.

Other source materials were also provided including: copies of the preliminary report; the construction plans and specifications; shop drawings; and all suppliers' catalogs and installation, operation, and maintenance instructions. Recent text books on water and sewage treatment and technical magazines in the field were also provided. In laboratory training, only two or three operators were assigned to each instructor, so that each operator could actually perform all of the tests under close supervision. The results of this training program were excellent. If the training had not been provided the plant doubtless never would have been operated successfully. During three years of plant operation there has been virtually no turnover in operating personnel, and the quality of operation as reflected in plant performance continues to improve.

To recruit and maintain a staff of good operators and maintenance men, they must be adequately paid and otherwise compensated. The current 1970-1971 pay classifications at South Tahoe are tabulated below:

Job Classification	1970 - 1971 Salary Range
Chief Operator	$880 - $1,134
Senior Operator	763 - 1,007
Operator, Grade I	715 - 885
Operator, Grade II	647 - 795
Solids System Operator, Grade I	737 - 912
Solids System Operator, Grade II	668 - 827
Plant Maintenance Supervisor	$737 - $ 912
Plant Maintenance Mechanic	668 - 827
Plant Electrician	822 - 1,071
Utility Man II	615 - 763

Operator Goals. In situations where there is a need for advanced wastewater treatment, as at Tahoe, there is also a need for much better and more consistent operation than is commonly provided in primary or secondary plants. The operation of primary and secondary plants is notably erratic and subject to frequent interruptions and shutdowns, and many such plants are never operated to their full capability or maximum efficiency. In general, the public is either not paying for good operation or is not getting the kind of operation that could reasonably be provided within available funds.

One of the objectives at South Tahoe was to demonstrate that a wastewater plant could be operated as efficiently and particularly as consistently as, say, a power generation station or a water purification plant. Before the Tahoe plant was placed in service many people were quite skeptical about the ability to keep what appeared to be a rather complex plant in continuous, uninterrupted operation and to produce consistently the high quality of water obtained in pilot plant tests of the process. It was thought that the extensive on-the-job operator training program would play an important part in securing the desired goal of good operation. The Board of Directors, the District employees, and the consulting engineers were all determined that the great effort and expenditures which had gone into conceiving, designing, financing, and constructing the plant would not be lost due to failure to properly operate or maintain the facilities. There is no doubt that this attitude and determination on the part of all parties directly involved with plant startup and its day-to-day operation and maintenance were essential to the complete success in all respects which was attained from the very start and during all three years of plant operation to date.

In almost every way the advanced treatment processes are easier to operate, control, and maintain than are the conventional biological processes of activated sludge and anaerobic sludge digestion. The plant was designed to be fail-safe. Sufficient flexibility in modes of operation and duplication of units are provided so that the plant can continue to operate with any unit out of service for servicing or repair. There are by-passes around individual plant units, but there is no way to bypass the entire plant.

As will be seen later upon examination of the detailed operating results, the South Tahoe Water Reclamation Plant has operated for the three-year period to date continuously and without interruption, and the high quality standards set by the regulatory agencies for the finished water have been met continuously and without exception. There is no longer any question whatever about the ability to practically operate the advanced wastewater treatment processes incorporated in this plant to their full theoretical potential. To do so does require adequate financing, the determination on the part of everyone involved in operation and maintenance, and the transfer of the knowledge from the plant designers to the operating personnel as to how the plant is intended to operate. There is no doubt that a formal, organized, on-the-job training program is essential. At South Tahoe, the dedication of the operating and maintenance staff, the skills they have developed and demonstrated, and the pride they have taken in setting a record of outstanding performance are a source of great satisfaction to all concerned with the project.

SECTION X

SAMPLE COLLECTION AND ANALYSIS

Automatic Sampling System. An automatic flow-integrated sampling system was operated from June 1968 to February 1971 by means of a flow activated timer. The rate of sewage flow entering the plant is measured by Parshall flumes. The signal from the flumes is received by an integrator-recorder which continuously records the gallons of sewage passing and transmits a signal to activate the time for the sampling system.

Pumps have been installed to supply a continuous stream of raw sewage, primary effluent, secondary effluent, carbon column effluent, and recarbonation basin effluent to the sample points. When the time is actuated, a solenoid valve opens for a pre-selected time and the sample stream flows into a one-gallon container. The sample containers are stored in refrigerators until they are ready for use. Samples of filter effluent and chlorinated final effluent are collected in a similar manner although pumps are not used.

Schedule of Sampling and Testing. During the course of the project there were two schedules used, one for the period of April 1968 to July 1970, and the other for July 1970 to February 1971, when the number of samples taken was reduced.

LABORATORY TESTING PROGRAM

April 1968 to July 1970

GRAVEYARD SHIFT

I. Pick up composite or grab samples (as necessary) from the following plant streams: Raw, Primary Effluent, Secondary Effluent, Separation Bed Effluent, Carbon Column Composite and Individual Column Effluents, and Chlorinated Effluents.

II. Unless specified, perform the following analyses on Monday, Tuesday, Wednesday, Thursday, Friday:

D.O. - Basins 1, 2, 3, 4, 5 & weir (all days)

Settleable Solids - Mixed liquor, activated sludge (all days)

Suspended Solids - Mixed liquor, activated sludge (all days)

B.O.D. - Raw, Sep. Bed Eff., Final Eff. (Monday & Wednes.)
Prim. Eff., Sec. Eff. (Tuesday & Thursday)
Raw, CC Comp., CCl-8, Final Eff. (Friday)

MBAS - Prim. Eff., Sec. Eff., Sep. Bed Eff., CC Comp., CCl-8 (Tuesday & Thursday)

NO_2 - Raw, Sec. Eff., CC Comp.

NO_3 - Raw, Sec. Eff., CC Comp.

Alkalinity - Raw, Sec. Eff., CC Comp.

pH - CC Comp. (all days)

DAY SHIFT

I. Pick up grab samples, as necessary, to do required analyses.

II. a. Collect total solids samples from Primary under Flow 1 & 2, day tank, sludge centrifuge cake and centrate, and lime centrifuge cake. (Set up tests, Swing Shift will finish them.)

b. Measure sludge centrifuge feed rate by drop in day tank at time of sample collection.

c. Measure lime centrifuge cake feed rate and wet density when collecting lime centrifuge cake sample.

III. Unless specified, perform the following analyses on Monday, Tuesday, Wednesday, Thursday, Friday:

D.O. - Basins 1, 2, 3, 4, 5 & weir (all days)

Settleable Solids - Mixed liquor, activated sludge (all days)

Suspended Solids - Mixed liquor, activated sludge (all days)

Chlorine - Final Eff., Luther Pass

COD - Prim. Eff., Sec. Eff., Chem. Clar. Eff., Sec. Recarb. Eff., Sep. Bed Eff., CC Comp., CCl-8

PO_4 - Raw, Prim. Eff., Sec. Eff., Chem. Clar. Eff., Sec. Recarb. Eff., Sep. Bed Eff., CC Comp.

Turbidity - Final Eff. (all days)

Total Solids - Final Eff. (See also Paragraph II a)

SWING SHIFT

I. Pick up grab samples, as necessary, to do required analyses.

II. Unless specified, perform the following analyses on Monday, Tuesday, Wednesday, Thursday, Friday:

D.O. - Basins 1, 2, 3, 4, 5 & weir (all days)

Settleable Solids - Mixed liquor, activated sludge (all days)

Suspended Solids - Mixed liquor, activated sludge (all days)
Raw, Prim. Eff., Chemical Clar. Eff., Sec. Recarb. Eff., Sep. Bed Eff., Final Eff., (Monday, Tuesday, Wednesday, Thursday, Friday)

CaO - Feed lime, recalcined lime from furnace, new lime from truck.

Color - Sep. Bed Eff., CC Comp., CCl-8

Volatile Suspended Solids - Mixed liquor

Total Volatile Solids - Sludge cent. cake

Total Solids - See Paragraph II a, Day Shift

Ca Hardness - Raw, Sep. Bed Eff., CC Comp. (Monday, Wednesday, Friday)

Chlorides - CC Comp. (Tuesday, Thursday)

Sulfates - CC Comp. (Tuesday, Thursday)

NH_3 - Raw, Sec. Eff., Strip Tower Eff., Final Eff.

LABORATORY TESTING PROGRAM

July 1970 to February 1971

GRAVEYARD SHIFT

I. Pick up composite or grab samples (as necessary) from the following plant streams: Raw, Primary Effluent, Secondary Effluent, Recarbonation, Separation Bed Effluent, Carbon Column Composite and Individual Column Effluents, and Chlorinated Effluents.

II. Unless Specified, perform the following analyses on samples which were collected on Sunday, Monday, Tuesday, Wednesday and Thursday:

D.O. - Basins 1, 2, 3, 4, 5 & weir (all days)

Settleable Solids - Mixed liquor, activated sludge (all days)

Suspended Solids - Mixed liquor, activated sludge (all days)

B.O.D. - Sep. Bed Eff., CC1-8, CC Comp., Final Eff.

MBAS - Sep. Bed Eff., CC1-8, CC Comp.

NO_2 - CC Comp.

NO_3 - CC Comp.

Alkalinity - CC Comp.

pH - Floc basin, 1st Stage Recarb., 2nd Stage Recarb., CC Comp. (all days)

DAY SHIFT

I. Pick up grab samples, as necessary, to do required analyses.

II. a. Collect total solids samples from Primary under Flow 1 & 2, day tank, sludge centrifuge cake and centrate, and lime centrifuge cake. (Set up tests, Swing Shift will finish them.)

b. Measure sludge centrifuge feed rate by drop in day tank at time of sample collection.

c. Measure lime centrifuge cake feed rate and wet density when collecting lime centrifuge cake sample.

III. Unless specified, perform the following analyses on Monday, Tuesday, Wednesday, Thursday, Friday:

D.O. - Basins 1, 2, 3, 4, 5 & weir (all days)

Settleable Solids - Mixed liquor, activated sludge (all days)

Suspended Solids - Mixed liquor, activated sludge (all days)

Chlorine - Final Eff., Luther Pass

COD - Prim. Eff., Sec. Eff., Chem. Clar. Eff., Sec. Recarb. Eff., Sep. Bed Eff., CC Comp., CC1-8

PO_4 - Raw, Prim. Eff., Sec. Eff., Chem. Clar. Eff., Sec. Recarb. Eff., Sep. Bed Eff., CC Comp.

Turbidity - Final Eff. (all days)

Total Solids - Final Eff. (See also Paragraph II a)

SWING SHIFT

I. Pick up grab samples, as necessary, to do required analyses.

II. Unless specified, perform the following analyses on Monday, Tuesday, Wednesday, Thursday, Friday:

D.O. - Basins 1, 2, 3, 4, 5 & weir (all days)

Settleable Solids - Mixed liquor, activated sludge (all days)

Suspended Solids - Mixed liquor, activated sludge (all days) Raw, Prim. Eff., Sec. Eff., Chem. Clar. Eff., Sec. Recarb. Eff., Sep. Bed Eff., Final Eff. (Monday, Tuesday, Wednesday, Thursday, Friday)

CaO - Feed lime, recalcined lime from furnace, new lime from truck.

Color - Sep. Bed Eff., CC Comp., CCl-8

Volatile Suspended Solids - Mixed liquor

Total Volatile Solids - Sludge cent. cake

Total Solids - See Paragraph II a, Day Shift

Ca Hardness - Raw, Sep. Bed Eff., CC Comp. (Monday, Wednesday, Friday)

Chlorides - CC Comp. (Tuesday, Thursday)

Sulfates - CC Comp. (Tuesday, Thursday)

NH_3 - Raw, Sec. Eff., Strip Tower Eff., Final Eff.

SECTION XI

TEST PROCEDURES

General. The test procedures used in the course of this project, with minor exceptions, are those prescribed by, "Standard Methods for the Examination of Water and Wastewater", as prepared and published jointly the American Public Health Association, the American Water Works Association, and the Water Pollution Control Federation, Twelfth Edition, 1965, except for those test procedures which are described in detail, hereinafter.

CALCIUM OXIDE.

Procedure.

1. Crush lime and weigh 1.000 gm sample.
2. Disperse in 200 ml volumetric flask with small amount of distilled water.
3. Add 50 ml Ammonium Chloride (NH_4Cl) and mix with magnetic stirrer for 3 minutes.
4. Dilute to 200 ml, mix, and take 25 ml sample.
5. Add about 100 ml of distilled water to the 25 ml sample, add 3 to 4 drops of a 20% solution of triethanolamine, and adjust the pH to 12.0+ with 20% NaOH.
6. Stir rapidly on magnetic stirrer and add Calcon indicator to medium red color.
7. Titrate with EDTA to pure blue end point while stirring rapidly to eliminate magnesium hydroxide floc interference.
8. If the end point is a violet color, and will not turn blue, the sample has too much magnesium in it and a smaller aliquote than 25 ml will be necessary. The percent available CaO should be corrected by the ratio of 25 ml to the number of ml used in the smaller aliquote.

Calculation. % Available CaO=(mls EDTA) (Correction Factor)

Reagents.

1. Ammonium Chloride (NH_4Cl) - 10 percent. Add 100 gm NH_4Cl to small amount of water and dilute to 1 liter.

2. Sodium Hydroxide (NaOH) - 20 percent. Add 100 gm NaOH to small amount of water and dilute to 500 ml.

3. EDTA ($Na_2H_2C_{10}H_{12}O_8N_22H_2O$)

Add 8.3 grams EDTA to about 500 ml water and put into solution by adding NaOH pellets. Dilute to 1 liter.

4. Triethanolamine - 20 percent. Dilute 200 ml of triethanolamine to 1 liter with distilled water

Standardization. Weigh out carefully 0.2 to 0.3 gms Calcium Carbonate ($CaCO_3$) and dissolve in 50 ml of water using concentrated Hydrochloric Acid (HCl). Perform normal CaO analysis beginning with step 3. Record mls EDTA

$$\text{Correction Factor} = \left(\frac{\text{gms } CaCO_3}{\text{mls EDTA for Stand.}}\right)(56)$$

APPARENT DENSITY TEST FOR ACTIVATED CARBON.

1. Weigh the 100 ml graduate cylinder supplied with the carbon shaker apparatus and record the weight in grams. (Weigh on trip balance).

2. Pour a sufficient amount of the carbon to be tested into the funnel at the top of the shaker, place the graduated cylinder under the shaker, and fill to the 100 ml mark at the rate of 1 ml/sec.

3. Weigh the graduate cylinder and carbon and record the weight in grams.

4. To calculate the apparent density, determine the weight of carbon in the full graduate and divide by 100.

$$\text{Weight Carbon} = \text{Weight Full Graduate} - \text{Weight Empty Graduate}$$

$$\text{Apparent Density} = \frac{\text{Weight Carbon}}{100}$$

5. Example

Weight Empty Graduate = 128.0 gm
Weight Full Cylinder = 176.6
Weight Carbon = 48.6

$$\text{Apparent Density} - \frac{48.6}{100} = 0.486 \text{ gm/ml}$$

CARBON ASH ANALYSIS. Ash is defined as the mineral oxide constituents of the carbon. Heating a sample to a temperature of 1750° F in an oxidizing atmosphere will completely oxidize all carbon and convert the mineral constituents to their respective oxides.

Procedure.

1. Grind a representative sample of carbon until 90 percent or more will pass a 325 mesh screen (by wet screen analysis).

2. Weigh 1.000 gram of pulverized sample into a weighed Vycor glass crucible without cover (see Note 1).

3. Place crucible and contents into a muffle furnace, set at 1750° F for 3 hours.

4. Remove from furnace, cool in desiccator and weigh. (Save crucible and ash for iron analysis, if desired).

5. Percent Ash is calculated as follows:

% Ash = 100 (final weight of crucible) - (original weight of empty crucible)

Notes on Method.

1. Although it is preferable to use Vycor glass, 30 ml capacity crucibles in this test, platinum or porcelain crucibles may also be used.

CARBON ISOTHERM PROCEDURE.

1. Pulverize a representative sample of the granular carbon (a 10-20 gram sample is usually adequate) so that 95 percent will pass through a 325 mesh screen. Oven dry the pulverized sample for three hours, at 150° C.

2. Obtain a representative sample of separation bed effluent.

3. Transfer four different weights of the oven dried pulverized carbon to the test containers. Spent carbon use 15,30,50, and 100 milligrams. Regenerated carbon use 5,10,25, and 50 milligrams. Stopped flasks or pressure bottles are satisfactory containers.

4. To one container add 500 ml of separation bed effluent from a graduate cylinder, and clamp the container on a mechanical shaker.

The samples must be constantly agitated during the isotherm test and a mechanical shaker is desirable. A Burrell Wrist Action Shaker, Catalog No. 75-775, is satisfactory. Agitate the mixture for the chosen contact time. The container may be filled and placed on the shaker at ten or fifteen minute intervals to give the analyst sufficient time to filter each sample immediately after the contact time has elapsed. The same volume of wastewater should be added to a container without carbon and subjected to the same procedure in order to obtain a blank reading.

5. After the chosen contact time has elapsed, filter the contents of the flask through either a laboratory pressure filter fitted with asbestos disk or through a Buchner funnel containing a filter paper (Whatman No. 3 or equivalent) inserted in a filter flask connected to a vacuum. The blank should be filtered in the same manner as the other samples. It is desirable to discard the first and last portions of the filtrate and save only the middle portion of analysis.

6. Immediately initiate procedure for determination of the chemical oxygen demand of the filtrate. MBAS (Methylene Blue Active Substances) may also be determined at this time.

7. Tabulate the data as shown in the following table. The residual solution COD or MBAS concentration, c, is obtained directly from the filtrate analysis. The amount adsorbed on the carbon, x, is obtained by subtracting the value of c from that of c_o, the influent concentration. Dividing x by m, the weight of carbon used in the test, gives the amount adsorbed per unit weight of carbon.

Tabulation of Isotherm Data

m Weight of Carbon (mg/1000 ml solution)	c Residual COD mg/l	x COD Adsorbed mg	x/m COD Adsorbed per Unit Weight

8. On log paper plot c on the horizontal axis against x/m on the vertical axis and draw the best straight line through the points, to obtain the isotherm.

9. The theoretical ultimate adsorptive capacity $\left(\frac{x}{m}\right) c_o$ can be obtained by finding on the vertical axis the point where the influent concentration, c_o, intercepts the isotherm.

THE IODINE NUMBER OF ACTIVATED CARBON. The Iodine Number is defined as the milligrams of iodine adsorbed by one gram of carbon when the iodine concentration of the residual filtrate is 0.02 normal.

Procedure.

1. Grind a representative sample of carbon until 90% or more will pass a 325-mesh sieve (by wet screen analysis).

2. Dry the sample for a minimum of three hours in an electric drying oven maintained at 150°C.

3. Weigh 1.000 gram of dried pulverized carbon (see Note 2).

4. Transfer the weighed sample into a dry, glass-stoppered, 250-ml Erlenmeyer flask.

5. To the flask add 10 ml of 5%-wt HCl acid and swirl until carbon is wetted.

6. Place flask on hotplate, bring contents to boil and allow to boil for only 30 seconds.

7. After allowing flask and contents to cool to room temperature, add 100 ml of standardized 0.1 normal iodine solution to the flask.

8. Immediately stopper flask and shake contents vigorously for 6 minutes.

9. Filter by gravity immediately after the 6-minute shaking period through an E & D folded filter paper.

10. Discard the first 20 or 30 ml of filtrate and collect the remainder in a clean beaker. Do not wash the residue on the filter paper.

11. Mix the filtrate in the beaker with a stirring rod and pipette 50 ml of the filtrate into a 250-ml Erlenmeyer flask.

12. Titrate the 50-ml sample with standarized 0.1 normal sodium thiosulfate solution until the yellow color has almost disappeared.

13. Add about 2 ml of starch solution and continue titration until the blue indicator color just disappears.

14. Record the volume of sodium thiosulfate solution used.

15. Calculate the Iodine Number as follows:

$$\frac{x}{m} = \frac{A - (2.2B \times \text{ml of thiosulfate solution used})}{\text{weight of sample (grams)}}$$

$$c = \frac{N_2 \times \text{ml of thiosulfate solution used}}{50}$$

$$\text{Iodine Number} = \frac{x}{m} D$$

X/m = mg. iodine adsorbed per gram of carbon
N_1 = normality of iodine solution
N_2 = normality of sodium thiosulfate solution
A = $N_1 \times 12693.0$
B = $N_2 \times 126.93$
C = residual filtrate normality
D = correction factor (obtained from attached graph)

Notes on Method.

1. The capacity of a carbon for any adsorbate is dependent of the concentration of the adsorbate in the medium contacting the carbon. Thus, the concentration of the residual filtrate must be specified, or known, so that appropriate factors may be applied to correct the concentration to agree with the definition.

2. The amount of sample to be used in the determination is governed by the activity of the carbon. If the residual filtrate normality (C) is not within the range 0.008 N to 0.035 N, given on the Iodine Correction Curve, the procedure should be repeated using a different size sample.

3. It is important to the accuracy of the test that the potassium iodide to iodine weight ratio is 1.5 to 1 in the standard iodine solution.

Reagents and Equipment. Hydrochloric Acid, 5%-wt - 445 ml of distilled water add 55 ml of reagent-grade concentrated hydrochloric acid.

Sodium thiosulfate, 0.1 normal - In a one-liter volumetric flask dissolve 24.82 grams of reagent-grade sodium thiosulfate crystals

($Na_2S_2O_3 \cdot 5H_2O$) in distilled water. Add about 0.1 gram of reagent-grade sodium carbonate and dilute to the one-liter mark. This solution should be allowed to stand for a few days before standardizing.

Standardize with reagent-grade metallic copper. Dissolve about 0.2 gram of copper, weighed to the nearest 0.1 mg, in 5 ml of concentrated nitric acid and boil gently to expel brown fumes. Dilute to about 20 ml with distilled water and add ammonia water dropwise until the solution is a deep blue color. Boil again until the odor of the ammonia is faint. Neutralize with acetic acid until the precipitate which forms with the acid dissolves and add 5 or 6 drops in excess. Again bring to boiling. Cool to room temperature. Add solid potassium iodide in sufficient amount to redissolve the copper iodide precipitate which forms. Titrate with sodium thiosulfate until the iodine fades to a light yellow color. Add starch indicator and continue the titration by adding the thiosulfate dropwise until a drop produces a colorless solution. Calculate the normality of the sodium thiosulfate as follows:

$$\text{Normality of sodium thiosulfate} = \frac{\text{weight copper}}{\text{ml thiosulfate} \times 0.06354}$$

Iodine Solution - Dissolve 12.7 grams of reagent-grade iodine and 19.1 grams of potassium iodide in distilled water. (See Note 3.) Dilute to one liter in a volumetric flask. To standardize the iodine solution, pipette 25.0 ml into a 250-ml Erlenmeyer flask and titrate with the standardized 0.1 N sodium thiosulfate. Use the starch indicator when the iodine fades to a light yellow color. Then finish the titration by adding the thiosulfate dropwise until a drop produces a colorless solution.

Calculate the normality of the iodine solution as follows:

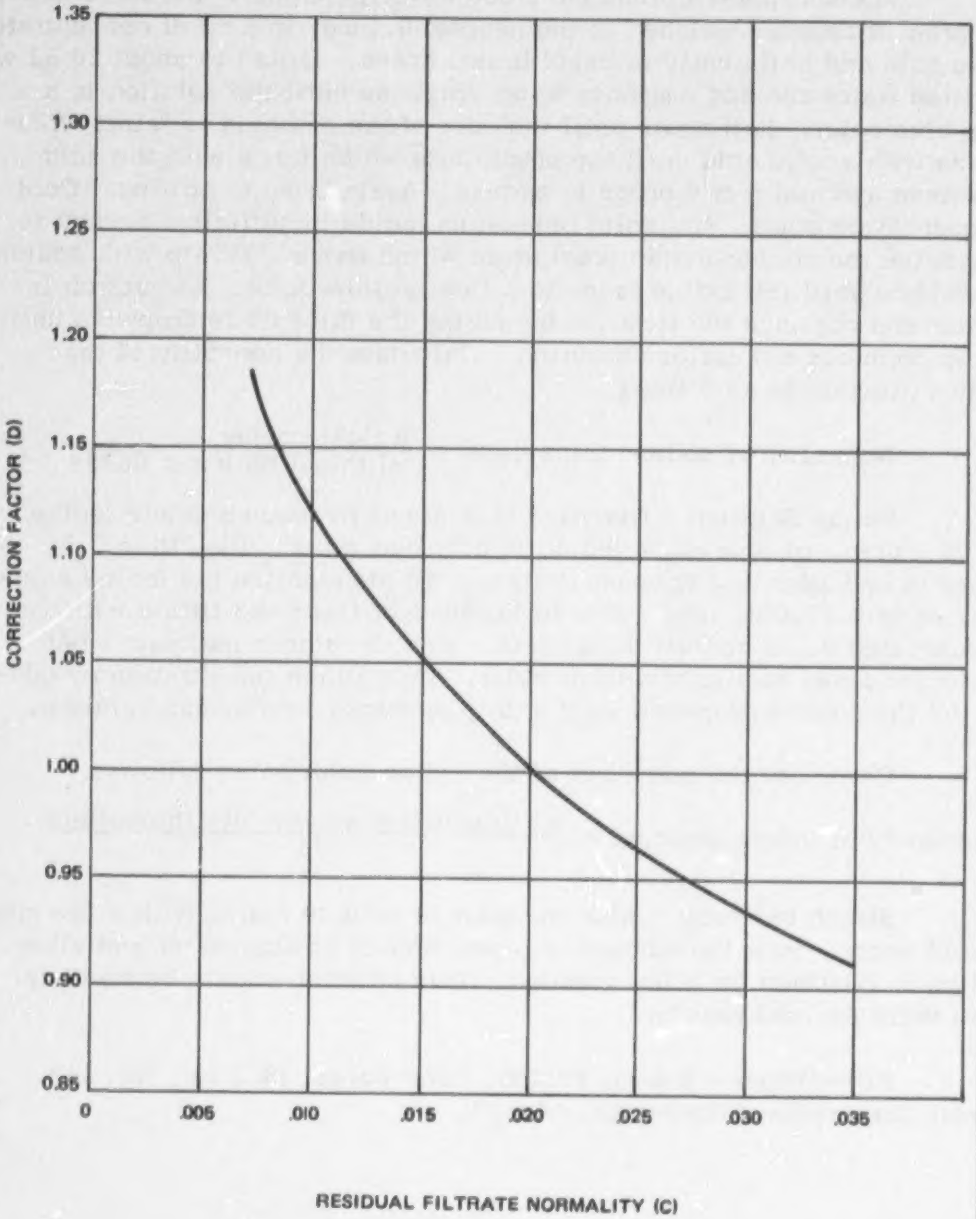
$$\text{Normality of iodine solution} = \frac{\text{ml thiosulfate} \times \text{normality thiosulfate}}{25}$$

Starch Indicator - Mix one gram of soluble starch with a few mls of cold water. Pour the mixture into one liter of boiling water and allow boiling to continue for a few minutes. This solution should be made up fresh daily for best results.

Filter Paper - E & D, Folded, filter paper, 18.5 cm, No. 192. Burrell Corporation Catalog No. 34-390.

FIG. 8

IODINE CORRECTION CURVE



SECTION XII

PRIMARY TREATMENT

Physical. Primary treatment facilities include a 2.7 mgd rectangular clarifier (No. 1) and a 4.8 mgd circular clarifier (No. 2). At design flow the rectangular clarifier has a detention time of 1.4 hours and an overflow rate of 1150 gpd/sf. The circular clarifier at design flow has a detention time of 2.4 hours, and an overflow rate of 610 gpd/sf. The weir loading for both clarifiers is 15,300 gal/ft/day. Each clarifier is provided with mechanical sludge collection. The rectangular clarifier is equipped with water spray scum collection, and the circular clarifier is equipped with both water sprays and mechanical scum collection. Active lime or alum can be fed to both clarifiers. A discussion of lime addition to the primary clarifiers is included in the chemical treatment section. Excess activated sludge is wasted to the primary clarifier. The primary clarifier underflow consisting of primary and waste activated sludge is degritted with a cyclone degritter before dewatering and incineration.

Treatment Efficiency. The raw sewage entering primary treatment is largely domestic and relatively low in strength. Average strength of the waste is shown in Table 2.

Table 2
Average Raw Sewage Characteristics
1970

BOD mg/l	140
Suspended Solids mg/l	225
Phosphorus (mg/l PO_4-P)	11
Total Dissolved Solids mg/l	315
NH_3-N mg/l	22
NO_2-N mg/l	.1
NO_3-N mg/l	.4
COD mg/l	200
MBAS mg/l	6

For the last 12 months of the grant period primary clarifier removals averaged 30% for BOD, 60% for Suspended Solids, 5% for Phosphorus, and NH_3-N, NO_2-N, NO_3-N increased very slightly.

SECTION XIII

ACTIVATED SLUDGE SECONDARY TREATMENT

Physical. Three plug-flow (0.9 mgd each) and two complete mix (2.4 mgd each) aeration basins, all in parallel, followed by two circular clarifiers at 2.0 mgd and 5.5 mgd comprise the conventional secondary facilities. For the plug flow basins at 2.7 mgd and 50% return sludge, a 5.1 hour aeration period is provided. The volumetric aeration period with 50% return sludge for each of the complete mix basins is approximately 3.5 hours, however, since the characteristics of complete mix basins result in the contents of aeration tank and the effluent being homogeneous, the actual aeration period will be shorter at design flows. The 2.0 mgd secondary clarifier has a detention time of 2.9 hours, a surface area of 2830 sf, and overflow rate of 700 gpd/sf, and a weir loading of 10,600 gal/ft/day. The 5.5 mgd secondary clarifier has a detention time of approximately 2.6 hours, a surface area of 7850 sf, an overflow rate of 700 gpd/sf, and a weir loading of 17,500 gal/ft/day. The 2.0 mgd secondary clarifier has a maximum sludge recirculation of 1380 gpm, and the 5.5 mgd secondary has a maximum rate of 3840 gpm.

Operational Practices. In order to achieve good ammonia removals through the ammonia stripping tower, it is necessary to operate the activated sludge system to prevent nitrification. To prevent nitrification, the load factor or food to microorganism ratio is usually maintained above 0.35, the mixed liquor suspended solids at 2000 mg/l, and the sludge age at 4-6 days. Also periodically the mixed liquor prior to clarification is dosed with 2 mg/l of chlorine to retard nitrifying bacteria. These practices have kept the secondary effluent NO_2-N concentration less than 0.1 mg/l and the NO_3-N less than 0.5 mg/l, with very little change in the NH_3-N across the secondary process.

Treatment Efficiency. During the year 1969, average percent removals across the secondary process included approximately 5% for Phosphorus, 60% for MBAS (Methylene Blue Active Substances), 65% for COD, 70% for BOD, and 75% for Suspended Solids. Across the entire conventional primary and secondary treatment process average percent removals were approximately 10% for Phosphorus, a slight decrease for Ammonia Nitrogen, 60% for MBAS, 65% for COD, 85% for BOD, and 90% for Suspended Solids.

It is important to recognize the effect of conventional treatment for organics, detergents (MBAS), and solids removal on the advanced waste treatment processes. The various advanced waste treatment processes normally remove a fairly constant percent of the organics, detergents, and solids applied to each process, with the exception of the mixed media filters which are nearly 100% efficient regardless of the solids concentration in the influent. If there are biological or mechanical malfunctions in the conventional processes, the concentration of chemical dosages, the number of backwashes, and the carbon dosage for the advanced waste treatment processes must all be increased or the final effluent quality will deteriorate. Since an effluent of constant quality and reliability is required for wastewater reuse, the provision for a possible poor quality water entering the advanced waste treatment processes must be considered in design.

An excellent example of the effect of secondary treatment on the advanced waste treatment processes is shown in Table 3. An approximate baseline for normal plant COD removals is depicted in the first line by showing the average removals for the entire year of 1969. In 1969, the secondary averaged 70% removal, 65% across chemical coagulation, recarbonation, and filtration, and 53% across the activated carbon. In comparison for the period March 23 to May 28, 1970, there was an apparent upset in the activated sludge process resulting in removal efficiencies around 30% for most of the period. Although the settleability and solids concentrations were normal, the effect of the poor secondary treatment on the activated carbon process and degree of carbon satuation is evident in Table 3. For instance, from March 23 to April 6, the secondary averaged 34% removal, chemical treatment through filtration 79%, and 39% for activated carbon. This period was immediately prior to a batch carbon regeneration and the carbon column effluent increased to 19 mg/l. The effect of carbon regeneration on the carbon column effluent with approximately the same prior treatment efficiencies is shown for the period April 7 to April 19. With the freshly regenerated carbon at the top of the columns, the carbon treatment efficiency increased to 68%, with an effluent value of 10 mg/l. From April 20 to May 10, there was an apparent increase in the strength of the waste, and the activated sludge process responded with near normal treatment efficiency. However, since the carbon was heavily loaded, the average carbon column effluent increased to 14 mg/l. For the next period, May 11 to May 28, the waste strength was normal, but the secondary efficiency decreased to 30%. However, the columns had freshly regenerated carbon at the top of the bed and the average carbon column effluent concentration decreased to 12 mg/l. From May 29 to June 22, the activated sludge was performing better at a 55% removal efficiency, which resulted in a lower COD concentration applied to carbon, 22 mg/l. However, it was at the end of a loading period

TABLE 3

THE AVERAGE PLANT PERFORMANCE FOR COD REMOVAL
January 1, 1969 to December 31, 1969
March 23, 1970 to June 22, 1970

Period	Primary Effluent	Secondary Effluent	Sep. Bed Effluent	Car. Col. Effluent	Comments
1-1-69 - 12-31-69	200	60	19	9	Plant performance for the year 1969, approximately normal treatment efficiencies.
3-23-70 - 4-6-70	222	147	31	19	Poor secondary efficiency, normal chemical treatment and filtration, prior to a batch carbon regeneration.
4-7-70 - 4-19-70	186	138	31	10	Poor secondary efficiency, normal chemical treatment and filtration, after a batch carbon regeneration.
4-20-70 - 5-10-70	340	121	32	14	Abnormally high secondary loading with near normal efficiency, normal chemical treatment and filtration, prior to a batch carbon regeneration.
5-11-70 - 5-28-70	188	132	32	12	Poor secondary efficiency, normal chemical treatment and filtration, after a batch carbon regeneration.
5-29-70 -6-22-70	180	81	22	12	Near normal secondary efficiency, normal chemical treatment and filtration, before a batch carbon regeneration.

for the carbon prior to regeneration, and the carbon treatment had a 45% removal efficiency, with an effluent concentration of 12 mg/l. From Table 3 , it is readily apparent that activated carbon plays an important role in maintaining an effluent of uniform quality in spite of normal, but undesirable, fluctuations.

The ammonia stripping process is dependent upon the operation of activated sludge system to prevent nitrification, so that the majority of the nitrogen present in the waste will be the ammonium ion, which can be converted to ammonia gas by pH adjustment and then air-stripped. Phosphorus removal does not necessarily depend upon conventional processes for initial removals, but the efficiency of phosphorus removal can be decreased by such problems as a considerable carryover of organic solids into the chemical coagulation process as a result of an upset in the activated sludge process.

SECTION XIV

DEWATERING AND INCINERATION OF WASTE ORGANIC SOLIDS

Physical. During normal operation, one 24" X 60" solid bowl, concurrent flow centrifuge is used to dewater the organic sludge mixture of primary and waste activated sludge. Incineration of the sludge is accomplished in a six hearth, 14.3 foot diameter, natural gas fired furnace. The furnace also dries the classified waste inert solids from the lime solids stream and the grit removal process. The waste lime, organic solids, and the grit pass through the furnace from top to bottom (hearth 1 at the top, and hearth 6 at the bottom). The furnace will have a maximum fuel consumption of 2.7 X 10^6 BTU/hr handling 21,000 lbs/day of waste solids at design capacity of 7.5 mgd and a cake solids content of 19%. After incineration and drying, the inert ash from the grit, waste organic and lime solids is carried by a bucket conveyor to an ash bin on the exterior of the incineration building. The ash bin is provided with a screw conveyor for loading dump trucks. Final disposal is to a private land fill. Two 45-foot diameter digestors, constructed in 1961 with the original conventional plant construction, are used for emergency storage of waste solids in the event of a breakdown in the dewatering or incineration system. See Figure 9.

Operational Practices. Excess activated sludge is wasted to the primary clarifier, where it settles with the primary sludge. The sludge combination is pumped from the primary clarifier at 1-2% solids through a cyclone degritter to a small holding tank. The solids are pumped from the holding tank at the same concentration to the centrifuges and dewatered, with over 90% capture, resulting in a cake solids concentration of approximately 18%. The centrate is returned to the primary. Approximately 2 to 5 lbs of a polyelectrolyte per ton of dry solids are required during the dewatering process. The organic solids cake and the waste inert lime solids from centrifugal classification of the lime solids stream are carried to the furnace by a belt conveyor. The waste lime solids have a solids content of approximately 30%. The grit from the cyclone degritter is conveyed with a screw conveyor directly to the top of the incineration furnace. In routine operation of the furnace, drying of the waste solids is accomplish-

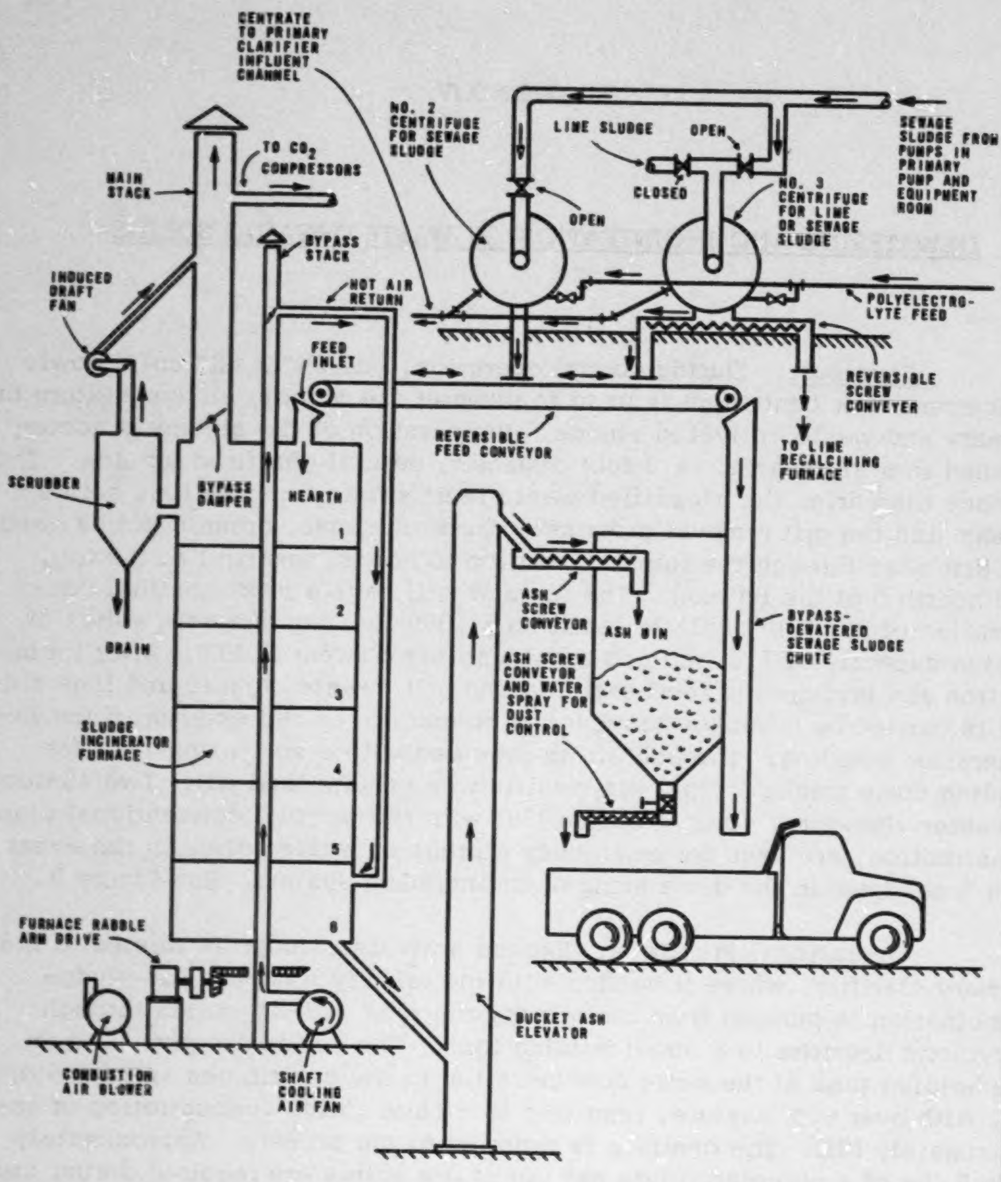

CENTRATE TO PRIMARY CLARIFIER INFLUENT CHANNEL
NO. 2 CENTRIFUGE FOR SEWAGE SLUDGE
LIME SLUDGE
OPEN
SEWAGE SLUDGE FROM PUMPS IN PRIMARY PUMP AND EQUIPMENT ROOM
CLOSED
NO. 3 CENTRIFUGE FOR LIME OR SEWAGE SLUDGE
OPEN
MAIN STACK
TO CO_2 COMPRESSORS
BYPASS STACK
INDUCED DRAFT FAN
HOT AIR RETURN
POLYELECTROLYTE FEED
FEED INLET
REVERSIBLE SCREW CONVEYER
REVERSIBLE FEED CONVEYOR
TO LIME RECALCINING FURNACE
SCRUBBER
BYPASS DAMPER
HEARTH
1
2
3
4
5
6
ASH SCREW CONVEYOR
ASH BIN
BYPASS-DEWATERED SEWAGE SLUDGE CHUTE
DRAIN
ASH SCREW CONVEYOR AND WATER SPRAY FOR DUST CONTROL
SLUDGE INCINERATOR FURNACE
FURNACE RABBLE ARM DRIVE
BUCKET ASH ELEVATOR
COMBUSTION AIR BLOWER
SHAFT COOLING AIR FAN

FIGURE 9
SOLIDS HANDLING
PRIMARY AND SECONDARY SLUDGE

ed on the first two hearths, incineration of the organic solids takes place on the third hearth, with possibly some on the fourth, and cooling on the fourth, fifth, and sixth hearths. A typical furnace hearth temperature profile would be:

Hearth No. 1	700°F
Hearth No. 2	1200°F
Hearth No. 3	1500°F
Hearth No. 4	1400°F
Hearth No. 5	1300°F
Hearth No. 6	500°F

The ash temperature leaving the furnace is approximately 200°F, and is naturally cooled in the conveying process to 100°F before it enters the ash bin. Table 4 shows the operating data for December 1969 to December 1970.

TABLE 4

ORGANIC SLUDGE FURNACE OPERATING DATA

December 1969 - December 1970

Plant Influent, mgd	2.45
Centrifugal	
Feed, % Solids	2.0
Cake, % Solids	17.0
Capture, %	91.0
Polyelectrolyte,lbs/ton(1)	5.1
Electricity,KWHR/day(2)	600
Organic Sludge Incinerator	
Feed, tons dry solids	921
Fuel requirements,BTU/lb(3)	7,640
Ash, cubic yds	970
Electricity,KWHR/day(4)	460

(1) Tons of dry solids to furnace.

(2) Includes energy and demand charges for feed pumps, centrifugal, and sludge conveyor.

(3) Natural gas at 18 psia and 860 BTU/ft^3.

(4) Includes energy and demand charges for furnace support motors and ash conveying system.

Stack Sampling Results. On November 10, 1970, three one hour stack sampling runs were made on the scrubber effluent of the multiple hearth incinerator. At the time of the sampling, the incineration furnace was being fed a combination of organic solids from the primary clarifier and waste lime from the centrifugal classification process of the lime solids recovery stream. The sampling and analysis of the stack gases were performed by a private laboratory, Ultra-Chem. The results of the sampling and analysis for sulfur compounds calculated as sulfur dioxide (SO_2) in ppm and combustion contaminants in grains per cubic foot of gas calculated to 12 percent carbon dioxide (CO_2) are shown in Table 5. Also the standards for the above parameters from Rule 53 of the Los Angeles County Air Pollution Control District Rules and Regulations are presented in Table 5.

TABLE 5

STACK SAMPLING RESULTS

MULTIPLE HEARTH INCINERATOR WITH COMBINATION LIME-ORGANIC SOLIDS FEED

November 10, 1970

	Test A	Test B	Test C	Rule 53
Combustion Contaminants:				
Grains/SCFM at 12% CO_2	.026	.014	.014	0.3
Oxides of Sulfur:				
(as SO_2) ppm	2.2	2.3	3.2	2000
Oxides of Nitrogen				
(as NO_2) ppm	52	65	-	

The average of the three runs for combustion contaminants was .018 grains/SCFM, which is 6% of that permitted by Rule 53. The average for oxides of sulfur was 2.6 ppm, which is less than 1% of the allowable according to Rule 53.

SECTION XV

CHEMICAL TREATMENT

During the period of the grant, chemical treatment studies consisted of active lime addition to the primary clarifier and to the secondary effluent. The addition of active lime to the primary clarifier was discontinued approximately five months after the grant studies were initiated because of problems in dewatering the lime-organic sludge mixture. This is described in detail later in this section. Lime coagulation and clarification of the secondary effluent was initiated at the start of the grant period and continues to the present. Excellent phosphorus removals plus additional solids and organics removals have been attained with the lime coagulation and clarification of the secondary effluent.

Primary Treatment. During the first five months after the expanded 7.5 mgd Water Reclamation Plant was put on line, recalcined lime was added to the primary clarifier to study its effect on clarification, as a wasting procedure to maintain the proper CaO content in the recalcined lime, and for phosphorus removal. Shortly after the addition of lime to the primary clarifier was initiated, problems arose in dewatering the mixture of primary, waste activated, and waste lime sludge in the centrifuges. Centrifuge problems included high torque and chatter, excessive wear on the conveyors, a high demand for sludge conditioners (polyelectrolytes), a wet centrifuge cake, and highly dispersed fines in the centrate. Several attempts were made to remedy the problem with different mixtures of the organic and lime sludges, but the above problems persisted. Also the centrate from the dewatering of the organic-lime sludge mixture was directed back to the primary clarifier during this period. This often resulted in increased concentrations of suspended solids and phosphorus in the primary effluent as compared to those found in the raw sewage. As a result of the dewatering problems, the practice of adding recalcined lime to the primary was discontinued in September, 1968. Since that time the lime and organic sludges have been dewatered separately with few problems.

During the latter portion of the period when recalcined lime was added to the primary, an attempt was made to dewater the organic-lime sludge mixture with a pilot (10 square foot) vacuum filter. The sludge mixture had a high demand for ferric chloride or for polyelectrolyte, which was thought to be a result of the waste lime in the organic sludge. It was determined that the chemical demand could be markedly reduced by adding sulfuric acid to the sludge mixture before adding the conditioners. However, the end result was that filtrate quality was no better than the centrate from the centrifuges and dewatering costs were approximately the same for both dewatering methods.

In spite of the dewatering problems, some intermittent data was collected across the primary clarifier during the recalcined lime addition period. For this period the pH in the primary effluent ranged from 7.5 to 11.0, with the majority of the results 9.5 or lower. When reasonable data was available across the primary clarifier, that is phosphorus and suspended solids removals, not increases, were attained, the phosphorus removals averaged about 20% and the suspended solids removals averaged slightly less than 50%. During the last 18 months of data collection at the end of the grant period when lime was not added to the primary, the phosphorus and suspended solids removals across the primary average less than 5% and between 50-60%, respectively.

After the decision was made to discontinue adding recalcined lime to the primary clarifier, the lime centrifuges have been used to classify inert materials out of the feed to the recalcining furnace. This has proven to be a more economical and effective way of maintaining the desired active lime content in the recalcined feed lime, rather than dewatering and recalcining the entire lime recovery solids stream and wasting a portion of the entire stream. A more detailed discussion of the centrifugal classification of the lime solids stream is included in the section on Lime Recovery and Reuse.

Activated Sludge. During the period when recalcined lime was added to the primary clarifier, the activated sludge continued to satisfactorily perform and produce the normal degree of treatment for organics removal. However, because of the earlier described dewatering problems with the primary sludge and the many variables such as sludge return rate, organic and solids loading, aeration period, and many others, very little specific data could be collected across the activated sludge system.

During the intermittent recalcined lime addition to the primary, at times the pH of the primary effluent reached above 11. Grab samples were taken of the return sludge-primary effluent mixture just before entering the aeration basins and approximately five feet into the aeration basins. When the mixture of primary effluent and return sludge was above pH 11.0, the pH five feet from the entrance was 8.5-8.6. Hence, it appears the activated sludge mixed liquor has a considerable buffering capacity for the high

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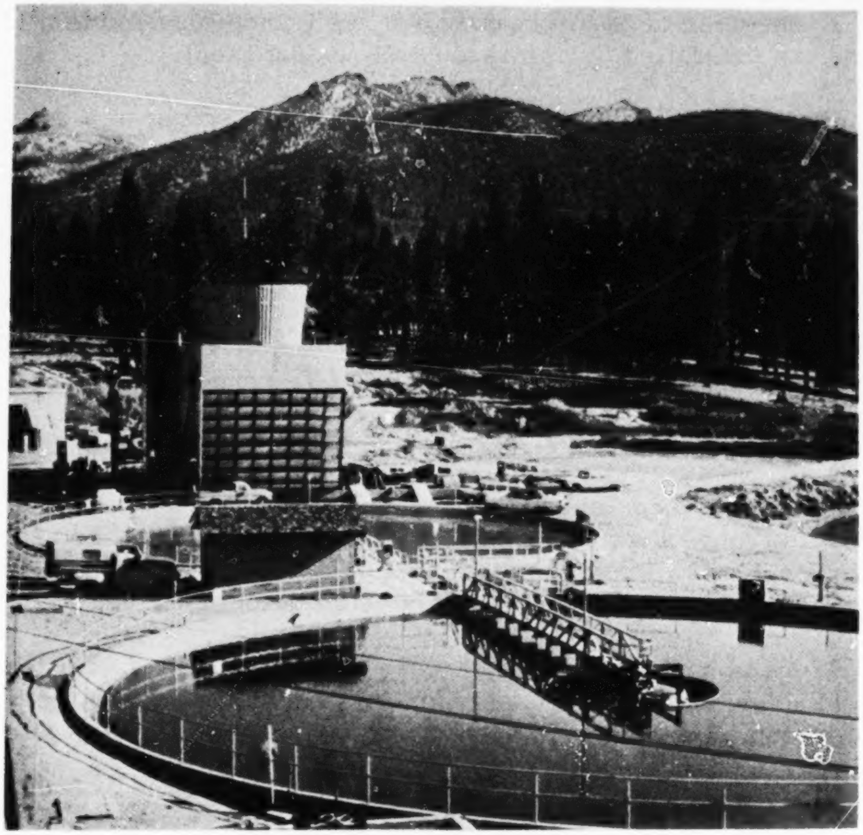


Figure 10

CHEMICAL RAPID MIX AND CLARIFIER
WITH SECONDARY CLARIFIER IN FOREGROUND AND
NITROGEN REMOVAL TOWER IN BACKGROUND

primary effluent pH under the lime addition to the primary mode of operation.

Lime Coagulation and Clarification of Secondary Effluent. The purpose of lime coagulation at South Tahoe are phosphorus removal from secondary effluent, clarification, and preparation of this effluent for ammonia stripping.

Recalcined and makeup lime are stored separately in identical 35 ton bins. Each bin is equipped with gravimetric lime feeders and pug-mill type slakers with 1500 lb. CaO/hr capacities. Bulk 16 X 50 mesh granular quicklime is used as makeup. The $Ca(OH)_2$ slurry is approximately one-fourth makeup and three-fourths recalcined lime. The slurry flows by gravity to the rapid mix chamber. Boxes are provided on the line to provide access for cleaning. Enough lime is added to raise the pH to about 11. This requires a lime dose of approximately 300 mg/l of calcium oxide. Lime feed rates are controlled by continuous pH measurement.

Rapid mixing is accomplished in a partitioned corner of a square 20 X 20 X 8 feet deep flocculation basin. At design flow of 7.5 mgd, there will be 30 seconds of rapid mixing, and 4.5 minutes of flocculation.

After flocculation, the lime treated secondary effluent flows to a conventional clarifier for removal of phosphorus rich lime mud and clarification. To improve clarification a polymer is added just as the water leaves the flocculation chamber. The polymer dose varies between 0.1 and 0.3 mg/l.

The clarifier is equipped with both a center sludge hopper and suction pipes attached to the clarifier mechanism. To date only the center sludge draw off has been needed. During the study period, the clarifier overflow rate ranged from 395 to 600 gal/ft^2/day, and detention times ranged from 4.6 to 3.0 hours. At the design capacity of 7.5 mgd, the overflow rate is 950 gal/ft^2/day and 1.9 hours detention time.

A discussion of the recycle streams and their point of addition to the process at South Tahoe is necessary before the data collection methods and results can be evaluated. There are six significant recycle streams:

1. Furnace Stack Gas Scrubber Water
2. Separation Bed Backwash
3. Lime Mud Thickener Overflow
4. Recycle Sludge from Chemical Clarifier
5. Organic Sludge Centrate
6. Lime Mud Centrate

The water reclamation plant effluent is used for supply of scrubber water to clean the sludge incineration and lime recalcining furnaces stack gases. This quantity is fairly constant, being about .65 mgd. The scrubber water is high in particulate material and has a temperature of about 80°F. The scrubber water can be returned to the process at primary clarification, the flocculation basin, or to the ballast ponds.

Separation bed (filter) influent is used to backwash the beds. The backwash water is collected in a 80,000 gallon tank. The tank can be operated as a decant tank with a variable period for clarification. The low turbidity water in the top two-thirds of the tank can be decanted back to the ballast ponds by means of a floating decant arm. The high turbidity water in the bottom of the tank can be drained through a sludge valve to the primary clarifier or the flocculation basin. The tank also can be operated to drain the entire contents of the tank through the sludge valve without clarification. Each backwash produces about 74,000 gallons of highly turbid water. There are an average of four backwashes every 24 hours.

The overflow from the lime mud thickening process can be returned to the primary or the flocculation basin. The overflow is clear and averages about .2 mgd.

A portion of the lime mud drawn off the chemical clarifier can be returned directly to the flocculation basin for seeding purposes. This flow is approximately 5 gpm. The centrates from the lime and organic sludge centrifuges are about 20 and 35 gpm, respectively. Both centrates are returned to primary clarification.

The major recycle flows, scrubber water, back wash, and lime mud thickener overflow, when mixed together, have a total quantity of over 1 mgd, a turbidity of approximately 70-100 Standard Jackson Units, and a total phosphorus concentration of about 7 mg/l PO_4-P. It is important to note that the recycle streams of scrubber water, lime mud thickener overflow, and decant tank sludge are all mixed together in a flow splitter box, before they are added to the plant processes. From this splitter box, the three flows may be introduced into either the primary clarifier or the lime flocculation basin. The scrubber water and/or the decant tank low turbidity water may also be returned to the ballast ponds which are situated between the lime coagulation and filtration systems.

Methods Used for Data Collection. Three methods of sampling were used to evaluate the efficiency of the chemical clarifier. For the first method, jar tests were performed to determine the optimum lime dose, and amount of recycle water for phosphorus and turbidity removal. Secondly, 24-hour composite samples were collected to evaluate on a plant scale, the efficiency of the chemical clarifier in removing not only phosphorus, but also organic materials and suspended solids under two different recycle schemes. Finally, grab samples were collected across the chemical clarifier for over a year to study the effect that the reintroduction of recycle water at different points in the plant had on phosphorus removal.

All the jar tests were performed in the following manner on 500 ml samples. Lime was added in varying amounts to each sample. The samples were flash mixed for 30 seconds at 100 rpm and flocculated for 5 minutes at 35 rpm. No polyelectrolytes were added. After one hour of clarification with no mixing, the clear liquor was analyzed.

A number of tests were run for which soluble, particulate, and total concentrations were reported. Materials passing a 0.45 micron filter were assumed to represent the soluble fraction. Particulate concentrations were determined by subtracting the concentration of the filtered sample from a parallel unfiltered sample.

Optimum Lime Dose. Lime doses from 200 to 700 mg/l CaO were added to 500 ml samples of secondary effluent to determine the optimum lime dose for phosphorus and turbidity removal. Figures 11 and 12 show the results of these tests.

Figure 11 indicates the optimum lime dose for phosphorus removal at South Lake Tahoe would be about 300 mg/l as CaO. An increase in lime dose from 200 to 300 mg/l CaO produced a seven percent increase in phosphorus removal; whereas an increase to 400 mg/l produced only a three percent increase in phosphorus removal. If the goal for phosphorus removal with excess lime treatment was greater than 86%, lime doses in excess of 200 mg/l CaO would be required in secondary effluents similar to those at South Lake Tahoe. Figure 13 shows the corresponding pH values.

A comparision of the turbidity removals, Figure 12, obtained during the same set of jar tests show that 300 mg/l CaO is close to the optimum dose.

Effect of Recycle Water. In an effort to improve phosphorus removals, the project staff, in July 1969, began recycling lime mud from the chemical clarifier to the lime rapid mix. Prior to this time, the average PO_4-P concentration in the final effluent had been 0.22 mg/l. During the next eight months after the addition of recycled lime mud, the final effluent averaged 0.16 mg/l PO_4-P.

FIGURE 11

PHOSPHORUS REMOVAL FROM SECONDARY EFF. VS LIME DOSE

(Jar Test)

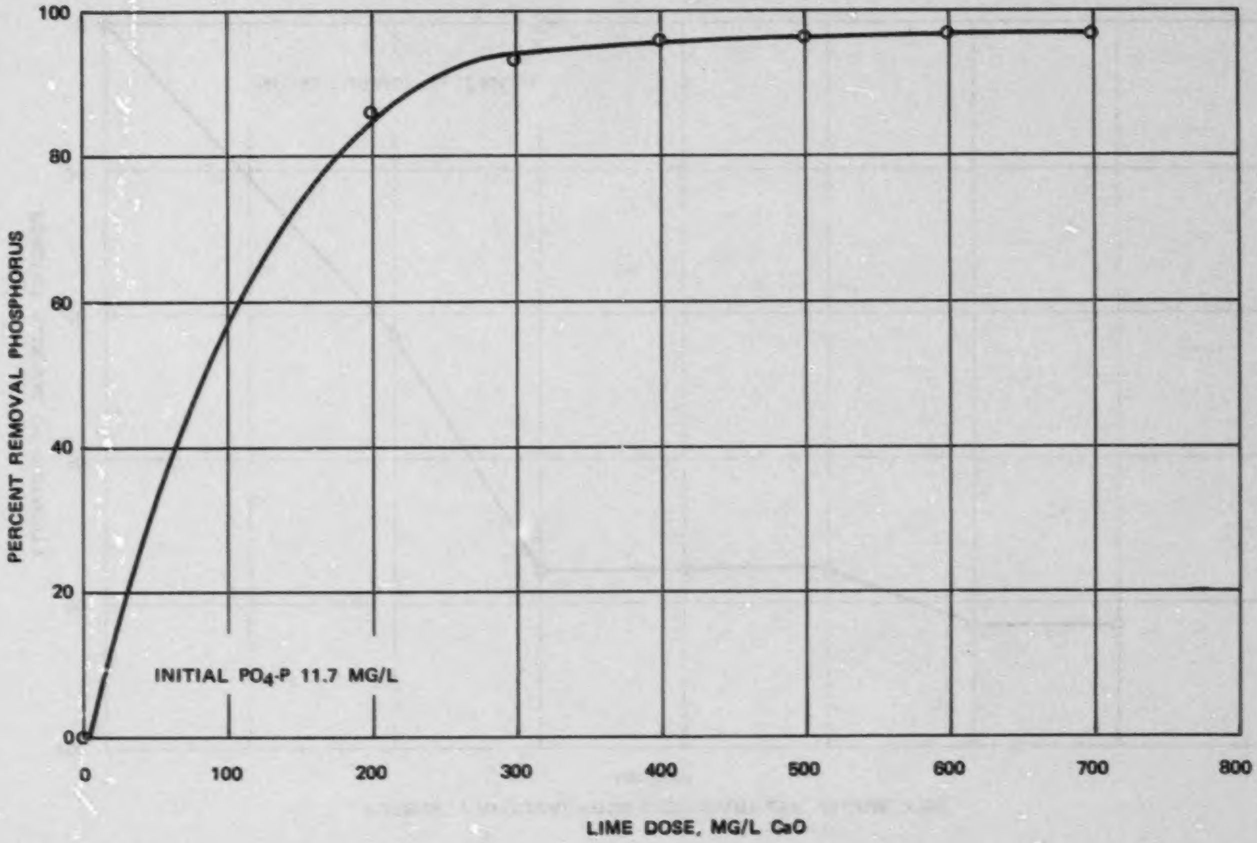


FIGURE 12

TURBIDITY REMOVAL FROM SECONDARY EFF. VS LIME DOSE

(Jar Test)

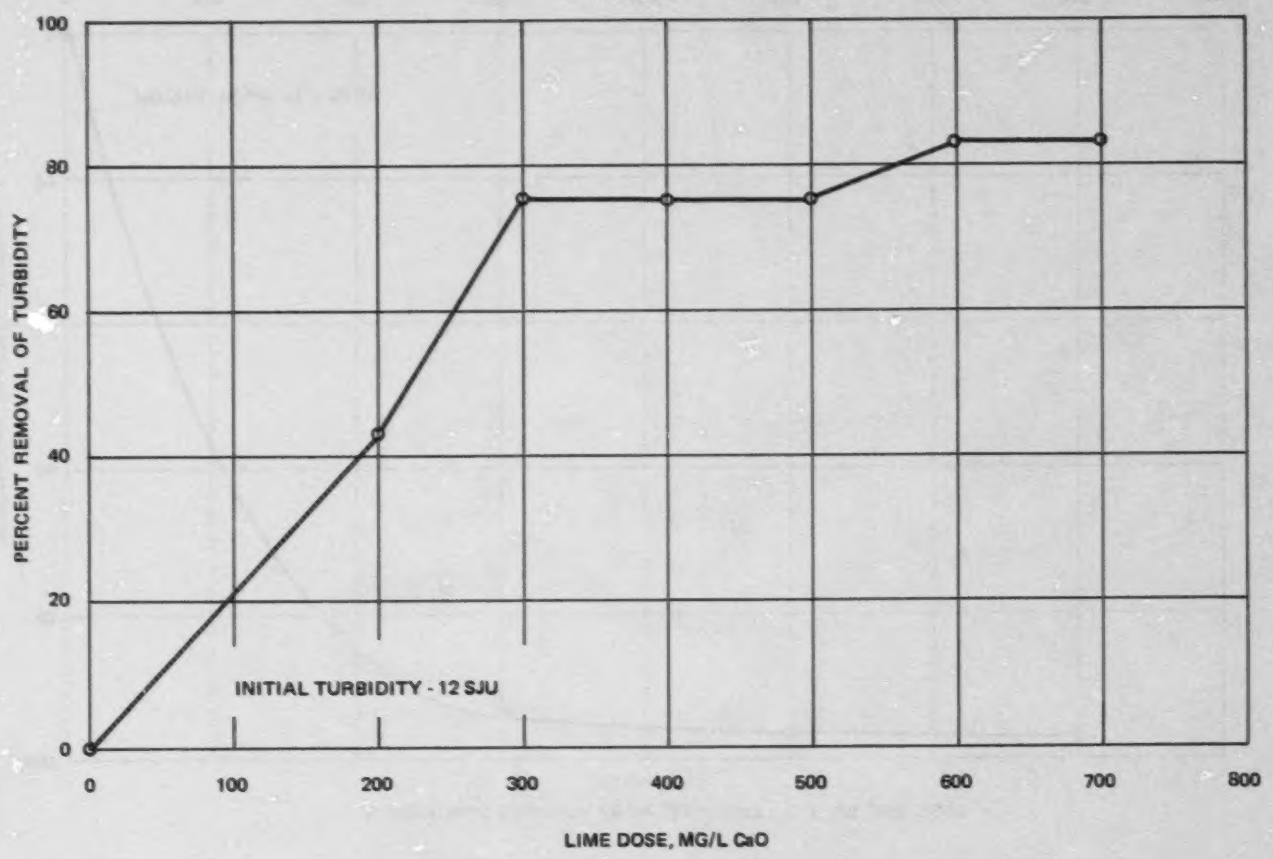
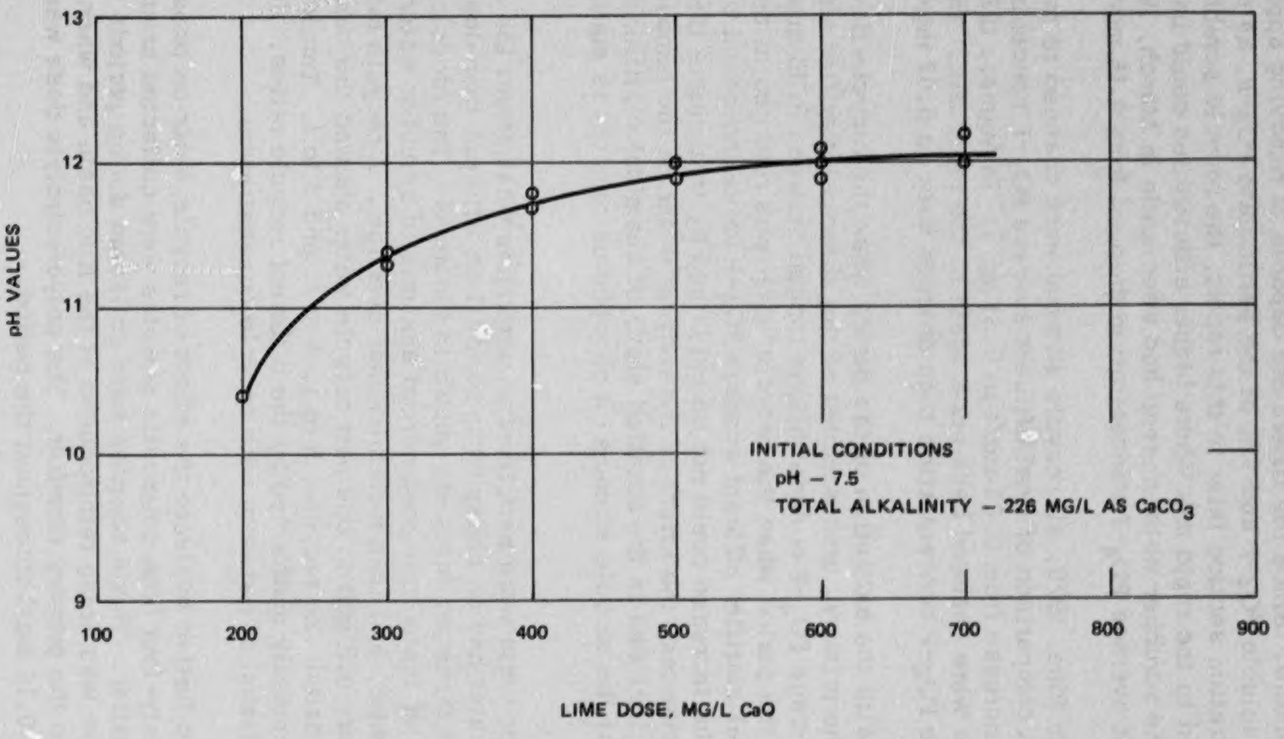


FIGURE 13

pH VS LIME DOSE



Ortho phosphorus (PO_4-P) studies of another recycle stream, scrubber water from the sludge and recalcining furnaces revealed a total concentration of 12.8 mg/l, of which 12.3 mg/l was particulate and 0.5 mg/l was soluble. Since the filters are capable of removing approximately 81% of the soluble PO_4-P and 91% of the particulate PO_4-P, as described in the filtration section later in this report, the recycle scrubber water was returned to the rapid mix where higher efficiencies could be obtained. After the scrubber water change had been made in March, 1970, the final effluent average PO_4-P concentration dropped from 0.16 mg/l to 0.09 mg/l.

In June, 1970, all recycle streams were changed to the primary clarfier. A comparison of final effluent average PO_4-P concentrations showed an increase from 0.09 mg/l to 0.31 mg/l. In August, 1970, the recycle streams were changed back once again to the rapid mix. The final effluent average PO_4-P concentration then dropped back to 0.07 mg/l.

With the exception of the period when the recycle flows were returned to the primary, grab samples of the chemical clarifier effluent showed that average PO_4-P concentrations ranged between 0.35 and 0.40 mg/l. During the period when the recycle water was returned to the primary, the chemical clarifier effluent average PO_4-P value increased to 0.76 mg/l. Since the increase could not be explained by inadequate lime dose or other circumstances, the effect of the recycle water on the removal of phosphorus was included in the detailed study of chemical clarifier efficiency. The effect of the recycle streams on phosphorus removal is summarized in Table 6.

Jar tests were performed to determine what effect the amount of recycle water had on phosphorus removal at different lime doses. The results of these jar tests are shown in Figure 14. The recycle water used for the jar tests contained normal amounts of scrubber water, filter backwash water, and lime mud thickener overflow. A recycle ratio of four parts secondary effluent to one part recycle water showed the best results of the ratios tested: no recycle, 6 to 1, 4 to 1, and 3 to 1. Turbidity removals were generally unaffected by the different recycle ratios. Table 7 shows the variation of turbidity with recycle concentration.

To further evaluate the effect of recycle water on phosphorus removal, twenty-four hour composite samples were collected around the chemical clarifier. These samples were collected during periods when the recycle water was being reintroduced at the floc basin and when it was being added to the primary clarifier. The polyelectrolyte dose was held between 0.1 and 0.16 mg/l throughout the period.

TABLE 6

PLANT SCALE EFFECT OF RECYCLE STREAMS ON AVERAGE PHOSPHORUS REMOVALS

Test Period	1 Jan. 69 to 1 July 69	1 July 69 to 14 Mar. 70	16 Mar. 70 to 8 June 70	10 June 70 to 24 Aug. 70	26 Aug. 70 to 18 Sept. 70
Point of Re-introduction of					
1. Scrubber Water (1)	Ponds(5)	Ponds	Floc Basin	Raw Sewage	Floc Basin
2. Filter Backwash (2)	Floc Basin	Floc Basin	"	"	"
3. Thickener Overflow (3)	"	"	"	"	"
4. Clar. Underflow (4)	none	"	"	"	"
Ratio of Plant Influent to Recycle Flow at Floc Basin	$\frac{4.5}{1}$	$\frac{4.7}{1}$	$\frac{1.8}{1}$	---	$\frac{2.4}{1}$
Phosphorus Concentration in Secondary Effluent, Effluent as mg/l PO_4-P (24 hr. composites)	6.0	8.6	9.0	8.4	12.8
Phosphorus Concentration in Chemical Clarifier Effluent as mg/l PO_4-P (Daily grab @ 10:00 hrs.)	---	0.40	0.35	0.76	0.35
Phosphorus Concentration in Final Effluent as mg/l PO_4-P (24 hr. composites)	0.22	0.16	0.09	0.31	0.07

---

(1) Scrubber water is from sludge and lime recalcining furnaces.

(2) Filter backwash water is from mixed media separation beds.

(3) Thickener overflow is from lime mud thickener.

(4) Clarifier underflow is a small sludge recirculation stream around the chemical clarifier.

(5) Ponds are ballast ponds located between the chemical clarifier and the separation beds.

FIGURE 14

EFFECT OF RECYCLE WATER
ON PHOSPHORUS CONCENTRATION
VS
LIME DOSE
(Jar Test)

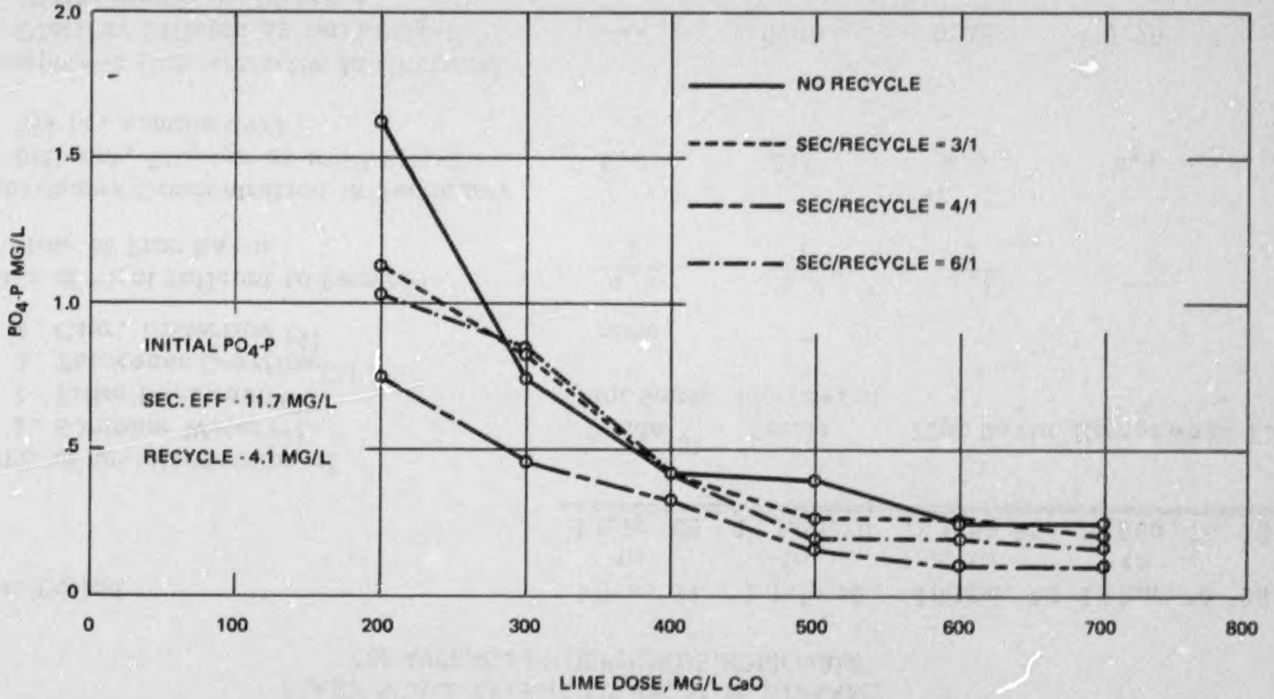


TABLE 7

EFFECT OF RECYCLE WATER ON TURBIDITY VS LIME DOSE

(Jar Tests)

	Settled Water Turbidity SJU			
Lime Dose mg/l CaO	Ratio: Secondary Effluent/Recycle Water			
	1/0	3/1	4/1	6/1
0	12	26	23	20
200	7	3	3	3
300	3	3	3	2
400	3	3	3	4
500	3	3	5	10
600	2	3	4	3
700	2	3	3	2

Secondary Effluent	12 SJU
Recycle Water	67 SJU

Table 8 shows that adding the recycle water to the floc basin greatly improved the removal of phosphorus reported as particulate phosphorus.

The removal of soluble phosphorus was not affected by the point of recycle water addition, by calcium oxide dosages between 200 and 500 mg/l, or by clarifier overflow rates between 400 and 600 gal/ft^2/day. However, the removal of total phosphorus, and the particulate phosphorus was affected by the point of recycle water addition and by calcium oxide dose. Between 400 and 500 gal/ft^2/day the overflow rate appeared to have very little effect on total phosphorus removal. Figure 15 shows that the calcium oxide dose affected total and particulate phosphorus removals when the recycle water was returned to the primary clarifier, and that CaO dose did not materially affect phosphorus removals when the recycle water was instead returned to the floc basin. Total phosphorus removals, as shown by Figure 16, were not changed by the overflow rates studied. The effect of adding the recycle water to the floc basin is also shown in Figures 15 and 16.

During the period when all recycle waters were being returned to the floc basin, thickened lime mud overflowed into the lime mud thickener launder continuously for several 24 hour periods. Twenty-four hour composite samples were collected around the lime coagulation system and analyzed. These results were not included in the previously reported results since they did not represent normal operating conditions. It is, however, interesting to compare the average of these results with those of normal operation. In Table 9 it can be seen that although the chemical clarifier effluent phosphorus concentration increased slightly, the percent removal of phosphorus across the chemical clarifiers improved because of the higher phosphorus concentration in the recycle water.

In Tables 10 and 11, the removal efficiencies for several parameters are shown for the two points of recycle water addition. It is important to note the similarities in the total and ortho phosphorus concentrations shown in the two tables. Practically all of the phosphorus measured is ortho, with very little polyphosphate present.

Although recycling the scrubber water back to the lime flocculation basin improved the plant phosphorus removal, this procedure led to higher lime costs due to the increased flow (0.65 mgd) and to the accelerated formation of hard scale in the transport line, which was difficult to remove.

Tests for the stability index (2 pH_s-pH) and Marble Test were performed on the lime mud thickener and the sludge and lime furnace scrubber

TABLE 8

THE AVERAGE EFFECT OF RECYCLE WATER ON CHEMICAL CLARIFIER EFFICIENCY

Parameter	Recycle Water Returned To Floc Basin		Recycle Water Returned To Primary Clarifier	
pH Floc Basin	11.0		10.9	
	% Removed	% Added	% Removed	% Added
Ortho Phosphorus				
Soluble (1)	99.4		99.7	
Particulate	73.4			177.
Total	93.4		85.8	
Total Suspended Solids	51.5			68.
Organic Suspended(2) Solids	89.2		87.5	
Turbidity	70.4			20

(1) Measured after filtration with .45 m filter

(2) Pretreated to pH 2 with HCl

FIGURE 15

TOTAL PHOSPHORUS REMOVAL
VS
CALCIUM OXIDE DOSE

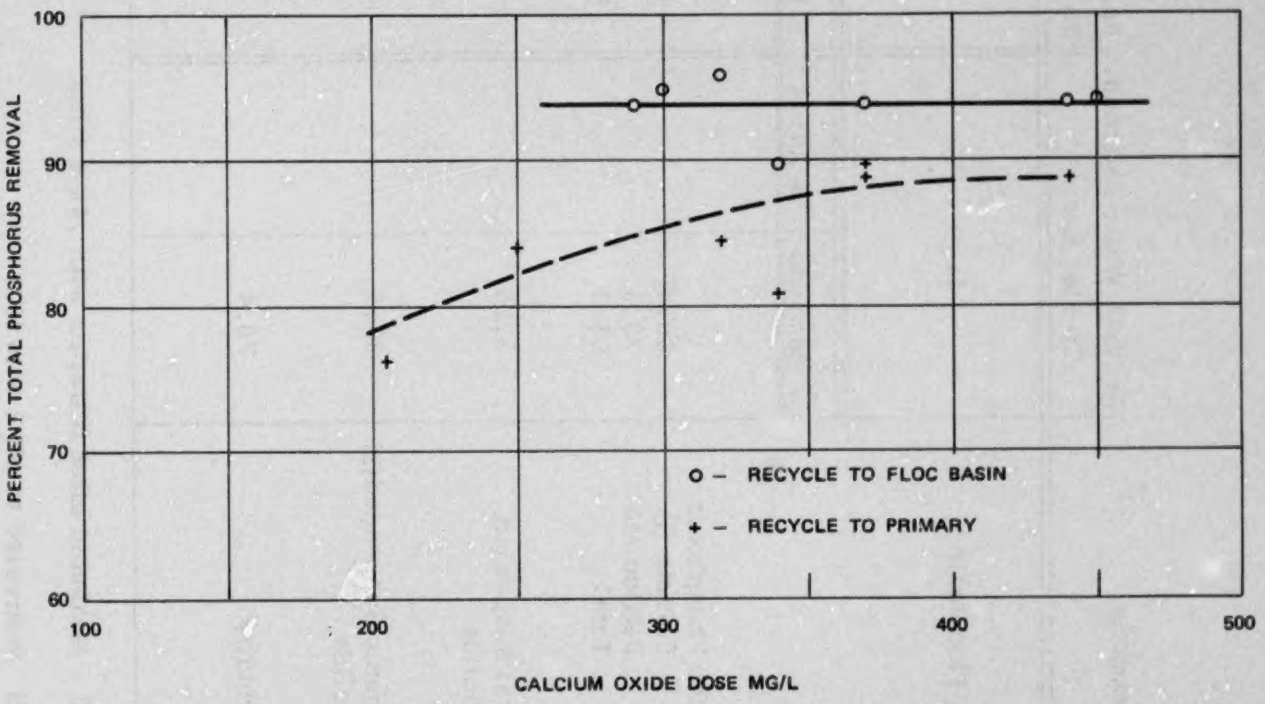


FIGURE 16

TOTAL PHOSPHORUS REMOVAL
VS
CLARIFIER OVERFLOW RATE

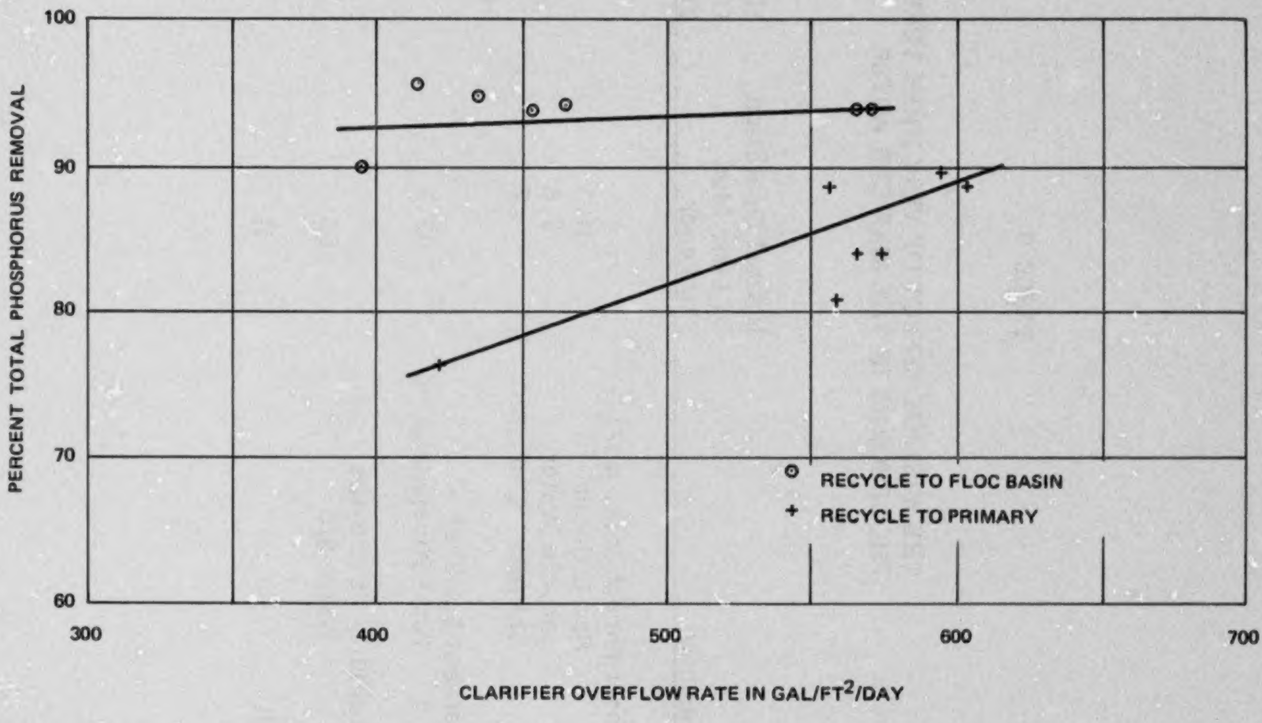


TABLE 9

THE AVERAGE EFFECT OF VERY HIGH TURBIDITY AND PHOSPHORUS IN THE RECYCLE WATER

Parameter	Normal Operation Of Lime Mud Thickener	High Solids Overflow Of Lime Mud Thickener
Total Phosphorus, mg/l		
Sec Effluent	11.3	9.9
Recycle Water	6.8	36.6
Chemical Clar. Eff.	.7	.8
Percent Removal of Total Phosphorus %	93.7	95.2
Turbidity of Recycle Water SJU	69	600
pH	11	11

TABLE 10

AVERAGE EFFICIENCY OF CHEMICAL CLARIFIER WITH RECYCLE WATER ADDED TO FLOC BASIN

Parameter (mg/l)	Average Concentrations			Percent
	Sec. Eff.	Recycle	Chem.Eff.	Removed
BOD				
Soluble	15.5	9.3	5.1	54.5
Particulate	23.8	12.8	3.8	80.5
Total	39.3	22.1	8.9	73.5
COD				
Soluble	44.3	23.2	30.8	26.4
Particulate	44.6	29.5	3.8	91.0
Total	88.9	52.7	34.6	57.8
Total Phosphorus(1)				
Soluble	10.33	0.53	0.03	99.7
Particulate	0.97	6.28	0.68	67.8
Total	11.30	6.81	0.71	93.7
Ortho Phosphorus				
Soluble	8.79	0.35	0.04	99.4
Particulate	1.81	5.49	0.62	73.4
Total	10.60	5.84	0.66	93.4
Total S.S.	38.	166	38.	51.5
Organic S.S.(2)	33.	29	6	89.2
Turbidity SJU	16	69	9	70.4
Color(3)(Cobalt Std.)	33	7	11	
Alkalinity, as $CaCO_3$	183	250	249	
Hardness as $CaCO_3$	73	152	145	
pH	7.2	7.7	11	

(1) Acid Digestion

(2) Pretreatment of sample to pH 2 with HCl

(3) Filtered at 0.45 microns

TABLE 11

AVERAGE EFFICIENCY OF CHEMICAL CLARIFIER WITH RECYCLE WATER ADDED TO PRIMARY CLARIFIER

Parameter (mg/l)	mg/l Average Concentrations		Percent Removed or Added (+)
	Secondary Eff.	Chemical Eff.	
BOD			
Soluble	3.4	0.8	76.5
Particulate	7.6	0.8	89.5
Total	11.0	1.6	85.5
COD			
Soluble	18.4	12.6	31.5
Particulate	22.1	4.2	81.0
Total	40.5	17.2	57.5
Total Phosphorus(1)			
Soluble	8.08	0.04	99.5
Particulate	0.36	1.24	254. (+)
Total	8.44	1.28	84.7
Ortho Phosphorus			
Soluble	7.28	0.02	99.7
Particulate	0.39	1.08	177 (+)
Total	7.67	1.10	85.8
Total S.S.	22	37	68.0 (+)
Organic S.S.(2)	19	3	87.5
Turbidity SJU	10	12	20 (+)
Color (3) (Cobalt Std.)	21	12	43
Alkalinity, as $CaCO_3$	226	286	
Hardness as $CaCO_3$	97	137	
pH	7.4	10.9	

(1) Acid Digestion
(2) Pretreatment of sample to pH 2
(3) Filtered at .45 microns

effluents. Table 12 shows that the thickener overflow had very high scale forming tendencies whereas the scrubber effluents were in equilibrium or slightly corrosive. It is suspected that the very large volume of warm, low pH, CO_2 rich scrubber effluent accelerated the scale forming tendencies of the CO_2 free, pH 11 lime mud thickener overflow.

Maintenance of Lime Mud Lines. About one year after plant start-up and prior to the addition of scrubber water, an increasing problem with calcium carbonate plating out on the lines handling lime mud and lime mud thickener overflow was encountered. An example of such buildup was observed in the 8 inch welded steel line which carried the lime mud thickener overflow and decant tank sludge. In the year of operation the diameter of this line had shrunk to 4 inches at the joint inspected. The lines were first chemically treated with no success. A pipe cleaning contractor with a cutting device that could be pulled through the pipe was tried next. The amount of time it took to clean 25 feet of pipe made the costs prohibitive. Finally, a device called a "Polly-Pig" manufactured by Knapp, Inc. was attempted for pipe cleaning. The pig is made of a polyurethane foam usually formed in a bullet shape with abrasive cutting edges on the exterior. At Tahoe, water pressure is used to expand the pig and force it through the pipe. The pigs can pass 90 degree turns, gate, check, and plug valves. The experience with the pigs as a pipe cleaning device has been very successful and cleaning of lime mud conveying lines has been established on a scheduled basis.

Additional Benefits of Chemical Coagulation and Clarification. During the plant scale chemical clarifier evaluation, data on several parameters other than phosphorus were collected to determine what additional benefits might be anticipated for removal of organics, particulate materials, and detergents.

As shown in Tables 10 and 11, Biochemical Oxygen Demand percent removals were somewhat better when the recycle streams were added to the primary clarifier. Particulate BOD removals were only slightly better, but soluble BOD removals were markedly better under this mode of operation, since the recycle streams had the benefit of biological treatment.

Chemical Oxygen Demand removals remained constant regardless of the point of addition of the recycle streams. As shown in Table 10 and 11, the total removals averaged slightly less than 60%. Figure 17 indicates the total COD percent removals were from 50 to 70 percent throughout the range of loadings.

Between 400 and 600 gal/ft^2/days, percent removals of BOD and COD were not affected by different flow rates.

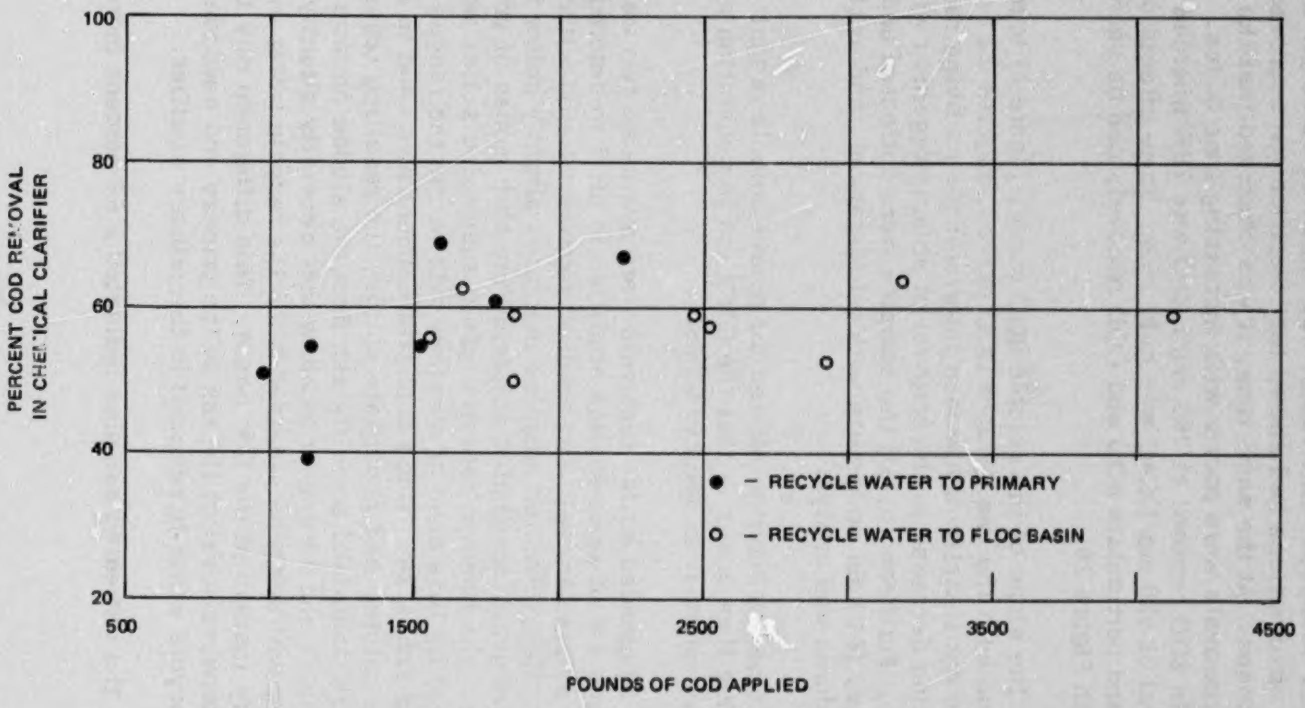
TABLE 12

STABILITY INDEX AND MARBLE TEST SCRUBBER WATER AND LIME MUD THICKENER OVERFLOW

Type of Sample	Scrubber Water		Lime Mud Thickener	Lime Mud Thickener (heated)
	Sludge Furnace	Lime Furnace		
Temperature ° F	62	80	50	80
Total Hardness, mg/l as $CaCO_3$	162	52	242	242
Total Alkalinity, mg/l as $CaCO_3$	357	440	362	363
Initial pH	6.8	7.1	11.3	11.2
Total Dissolved Solids, mg/l	312	310	300	300
Stability Index ($2pH_s$-pH) Scaling $<6.0>$ Corrosive	7.5	7.2	2.8	2.4
Marble Test				
Total Alkalinity, mg/l as $CaCO_3$ (a, untreated)	255	324	326	363
Total Alkalinity, mg/l as $CaCO_3$ (b, treated)	255	330	346	337
Results:				
$a > b$ scale forming			X	X
$b > a$ corrosive		X		
$a = b$ equilibrium	X			

FIGURE 17

POUNDS OF TOTAL COD APPLIED
VS
PERCENT COD REMOVAL



However, BOD and COD removals were affected by lime dosages between 205 and 450 mg/l as CaO, and by corresponding pH values between 10.5 and 11.3. The removal of total BOD and COD improved with increasing lime dosages. This result was expected since jar tests and plant scale observations had shown that clarification improved with increasing lime doses. At the same time, it was observed that the soluble BOD and COD removals were poorer with increasing lime doses. For example, the soluble BOD removal at 290 mg/l CaO was 78% whereas the soluble BOD removal at 450 mg/l CaO was only 25%. Some effects of lime dose on soluble and particulate BOD and COD removals can be seen in Figure 18 through Figure 26.

The slope of the soluble BOD curve, Figure 19 together with the correlation with the two soluble COD curves, Figures 22 and 25, would seem to rule out toxicity or nitrogen interferences as being responsible for the resulting decrease in the removal of soluble organics with increasing lime doses. Furthermore, all the samples were collected under the same conditions, (24 hour composite with refrigeration), and analyzed by the same procedures and analyst.

One explanation offered for poorer soluble organic removals with increasing lime doses is that the OH^{-1} ion is converting some particulate organic material to soluble forms.

Suspended solids removals were evaluated two ways. Before filtering, one set of samples was acidified to pH 2 to determine the actual organic solids removal, and another set was filtered without acid pretreatment. The pretreated samples indicated slightly below 90 percent removals of organic suspended solids during both modes of process recycle addition. The removal rate of organic suspended solids was not materially affected by lime dose or overflow rate within the ranges shown by Figure 27 and Figure 28. Since acid pretreatment was used to dissolve particulate calcium and phosphate solids, the resulting organic suspended solids still contained some fly ash from the sludge furnace scrubber. Both Figures 27 and 28 appear to show that generally slightly better organic solids removal could be obtained when the recycle water was returned to the primary instead of the floc basin. This difference may be caused by the additional removal of fly ash in the primary and secondary clarifiers when the recycle water is returned to the primary clarifier.

The untreated samples indicated a 68 percent increase in total sus-

FIGURE 18

TOTAL BOD REMOVAL
VS
LIME DOSE
RECYCLE STREAMS TO FLOC BASIN

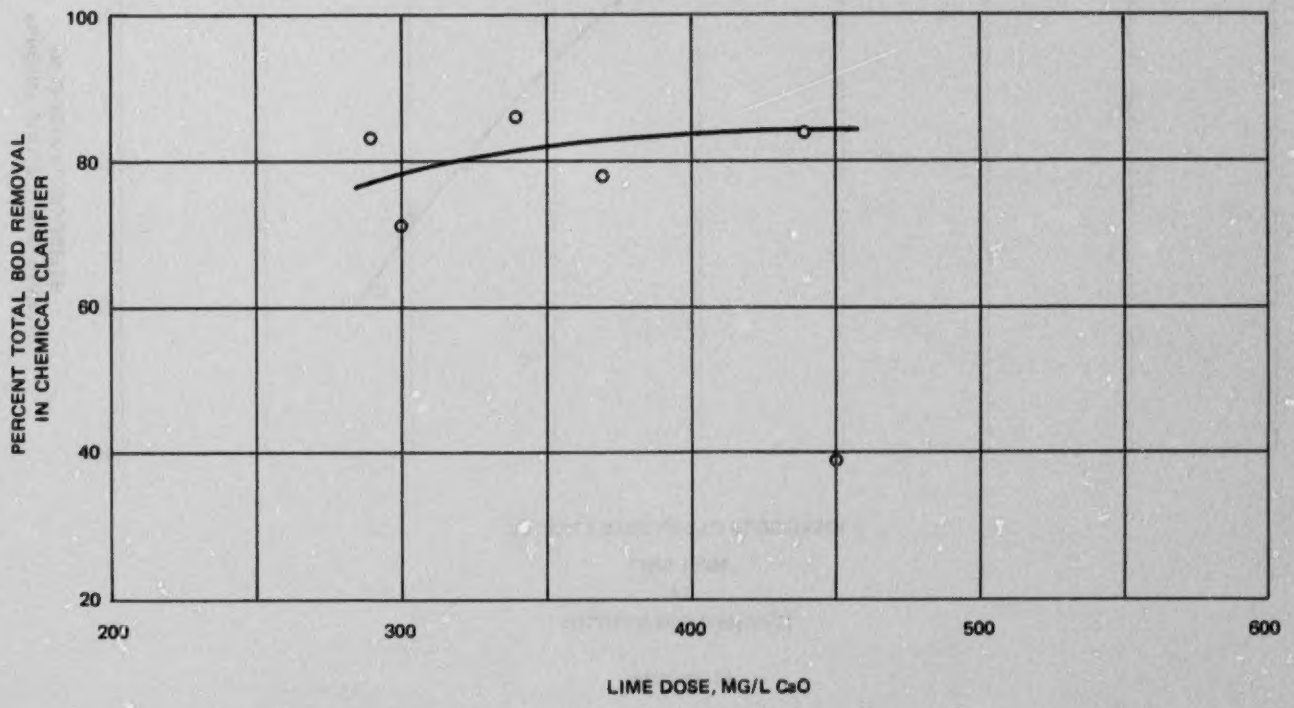


FIGURE 19

SOLUBLE BOD REMOVAL
VS
LIME DOSE
RECYCLE STREAMS TO FLOC BASIN

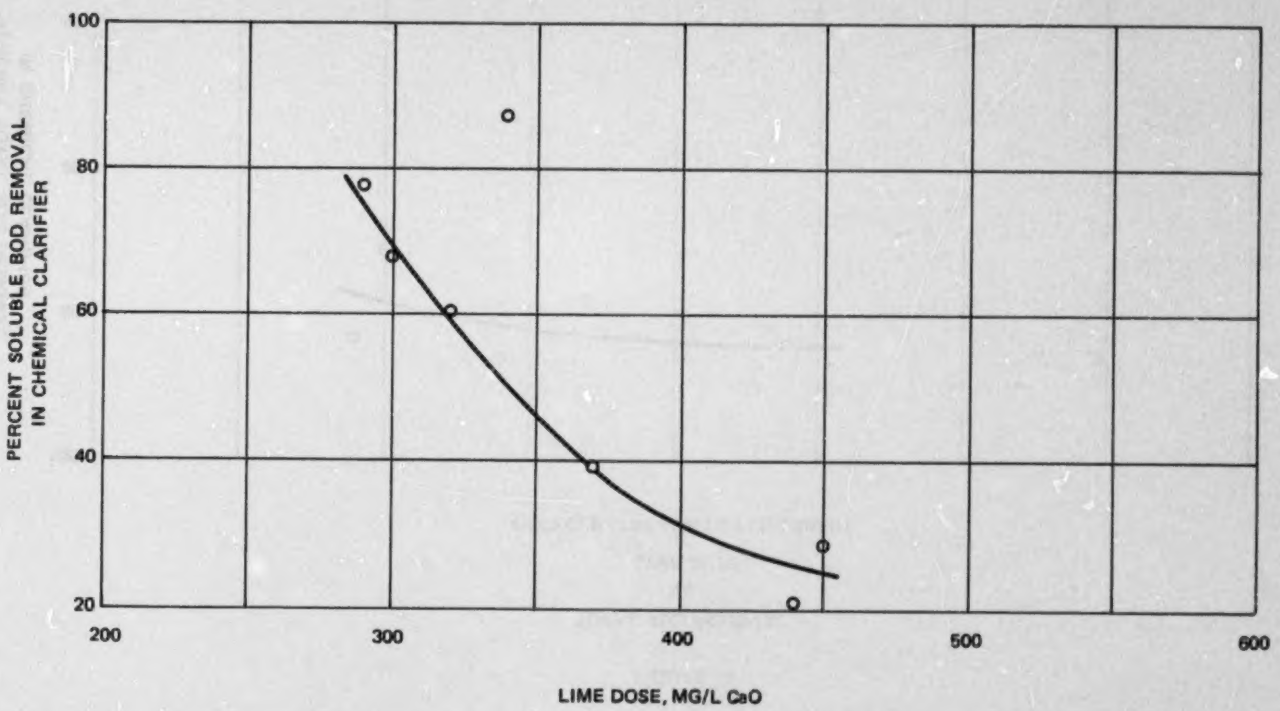


FIGURE 20

PARTICULATE BOD REMOVAL
VS
LIME DOSE

RECYCLE STREAMS TO FLOC BASIN

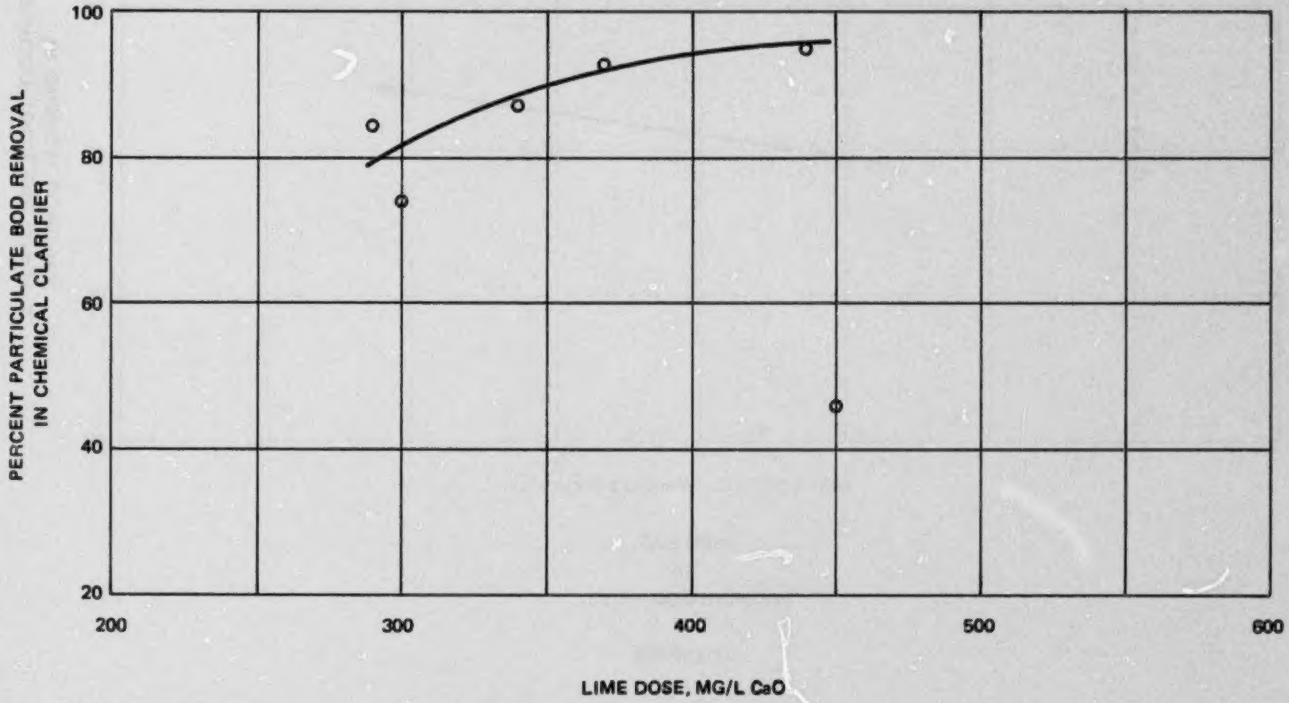


FIGURE 21

TOTAL COD REMOVAL
VS
LIME DOSE

RECYCLE STREAMS TO FLOC BASIN

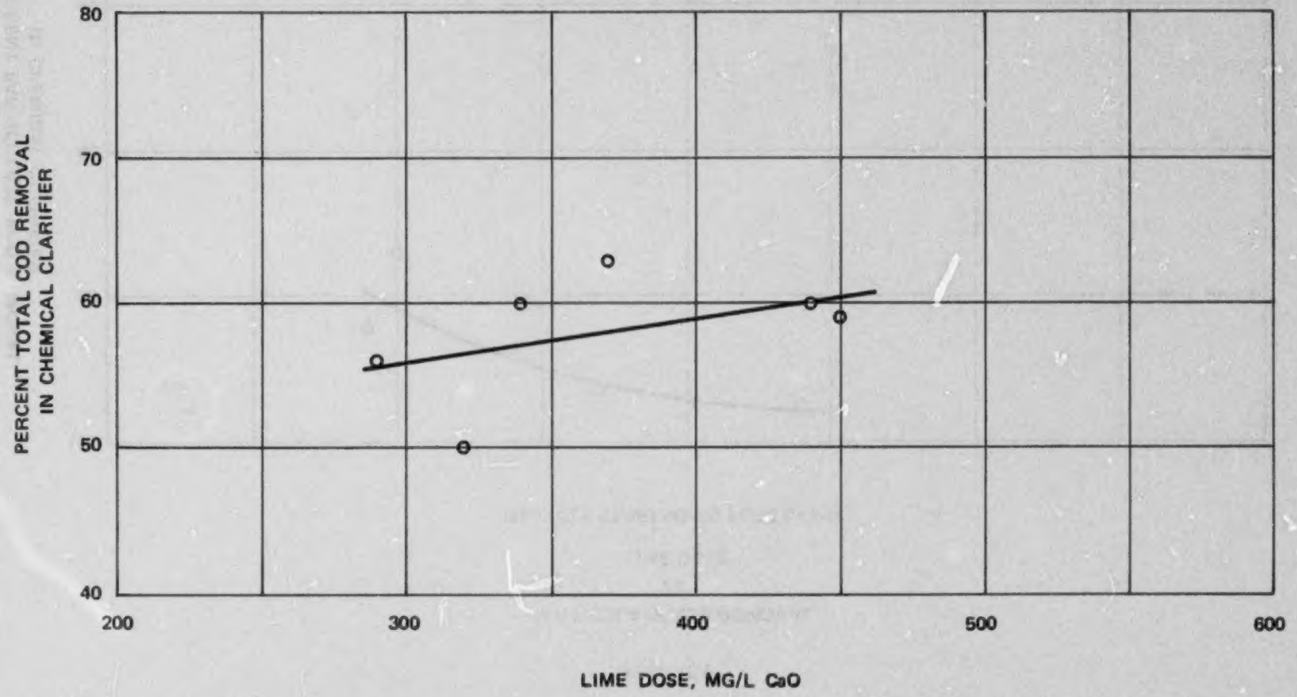


FIGURE 22

SOLUBLE COD REMOVAL
VS
LIME DOSE

RECYCLE STREAMS TO FLOC BASIN

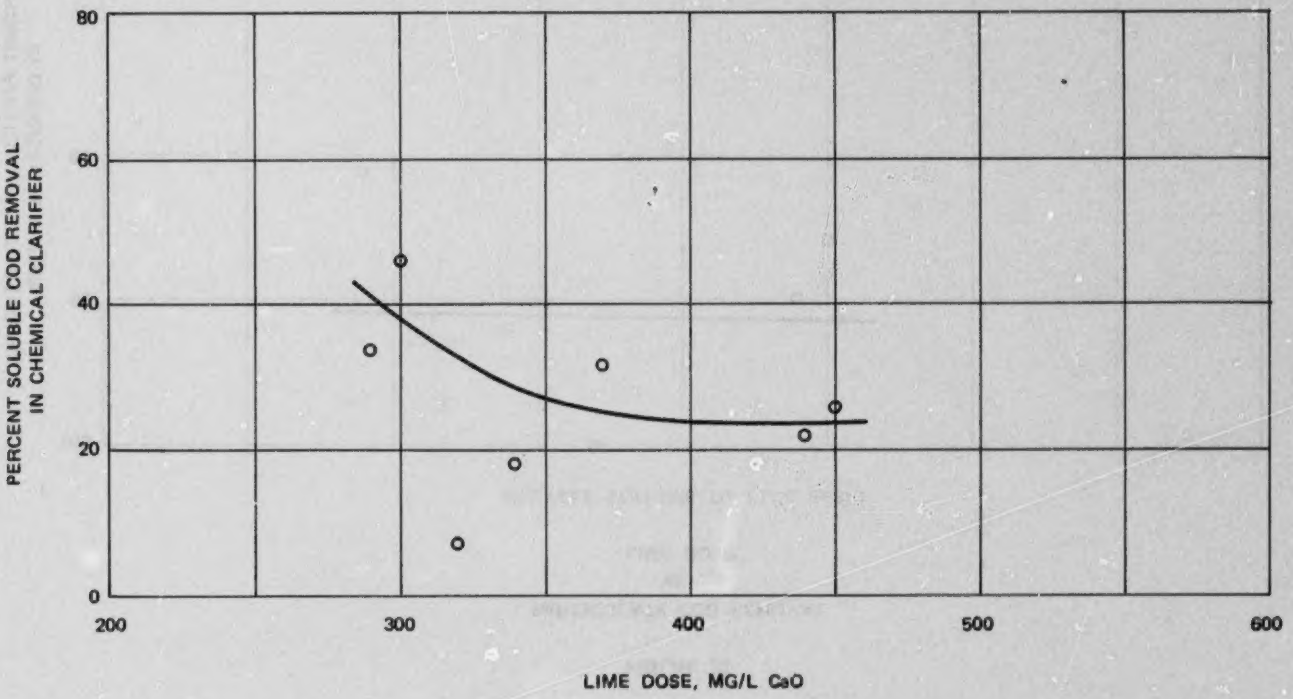


FIGURE 23

PARTICULATE COD REMOVAL
VS
LIME DOSE

RECYCLE STREAMS TO FLOC BASIN

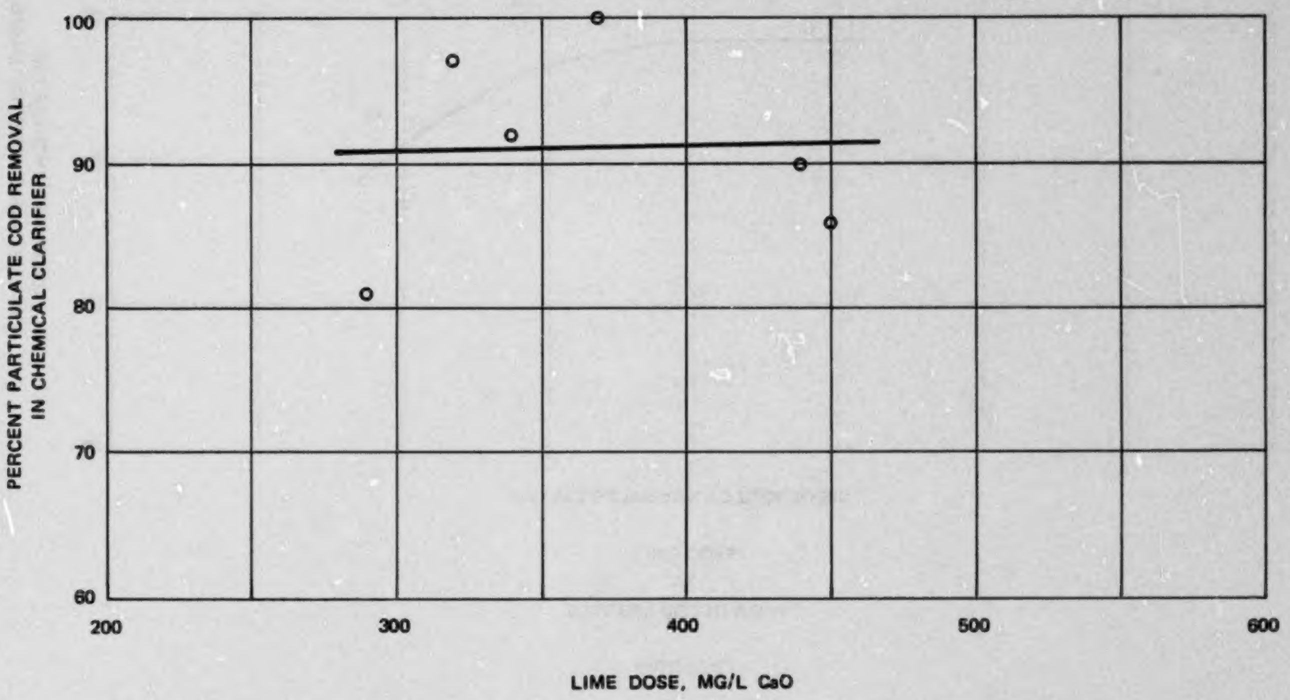


FIGURE 24

TOTAL COD REMOVAL
VS
LIME DOSE

RECYCLE STREAMS TO PRIMARY

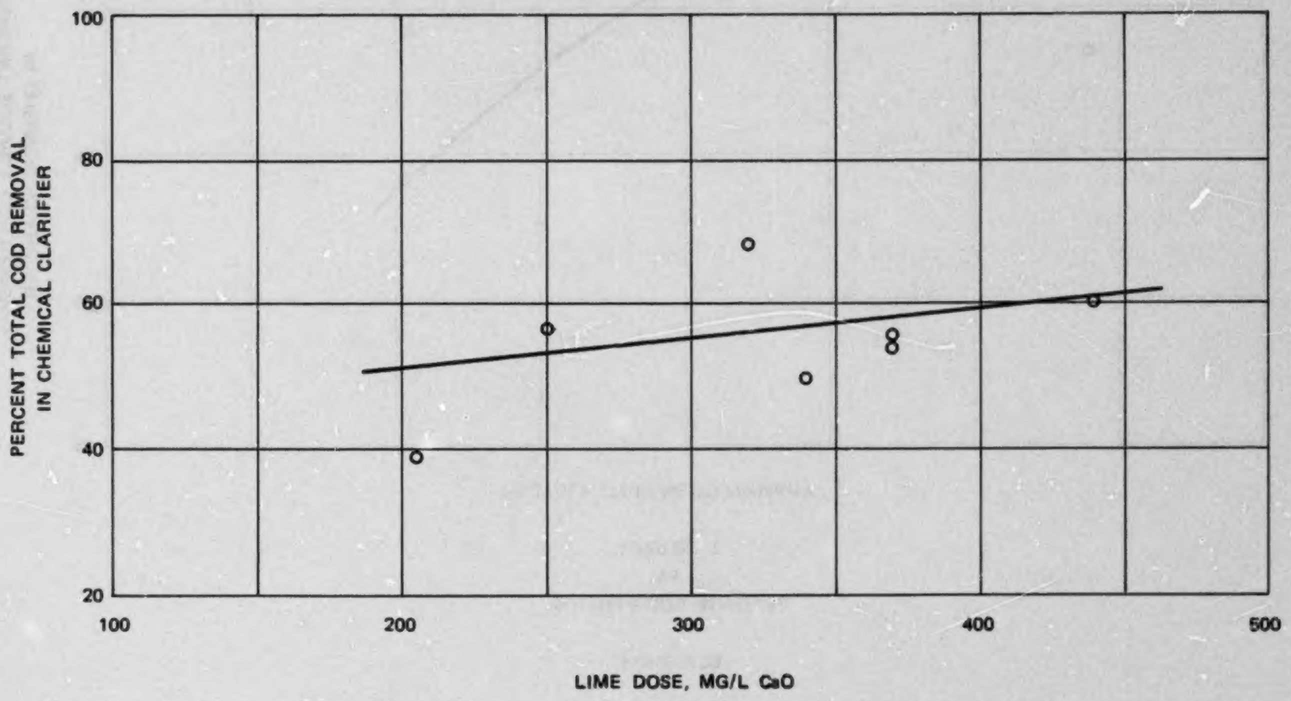


FIGURE 25

SOLUBLE COD REMOVAL
VS
LIME DOSE

RECYCLE STREAMS TO PRIMARY

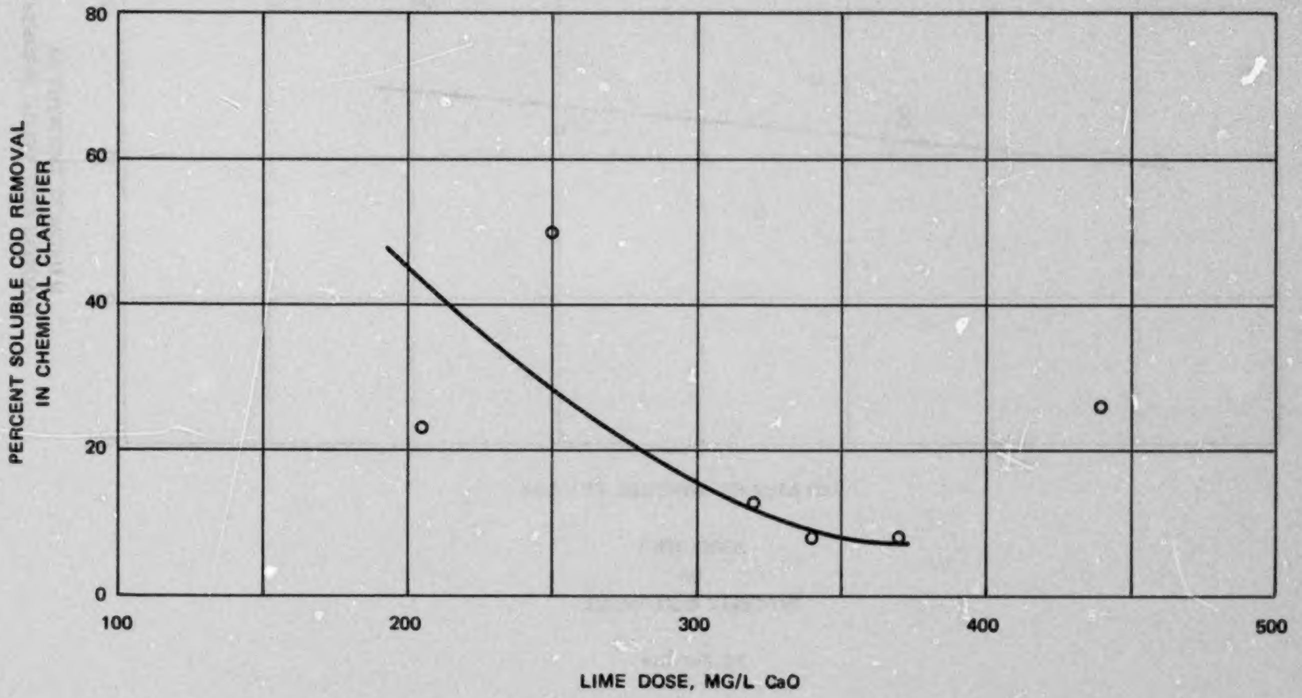


FIGURE 26

PARTICULATE COD REMOVAL
VS
LIME DOSE

RECYCLE STREAMS TO PRIMARY

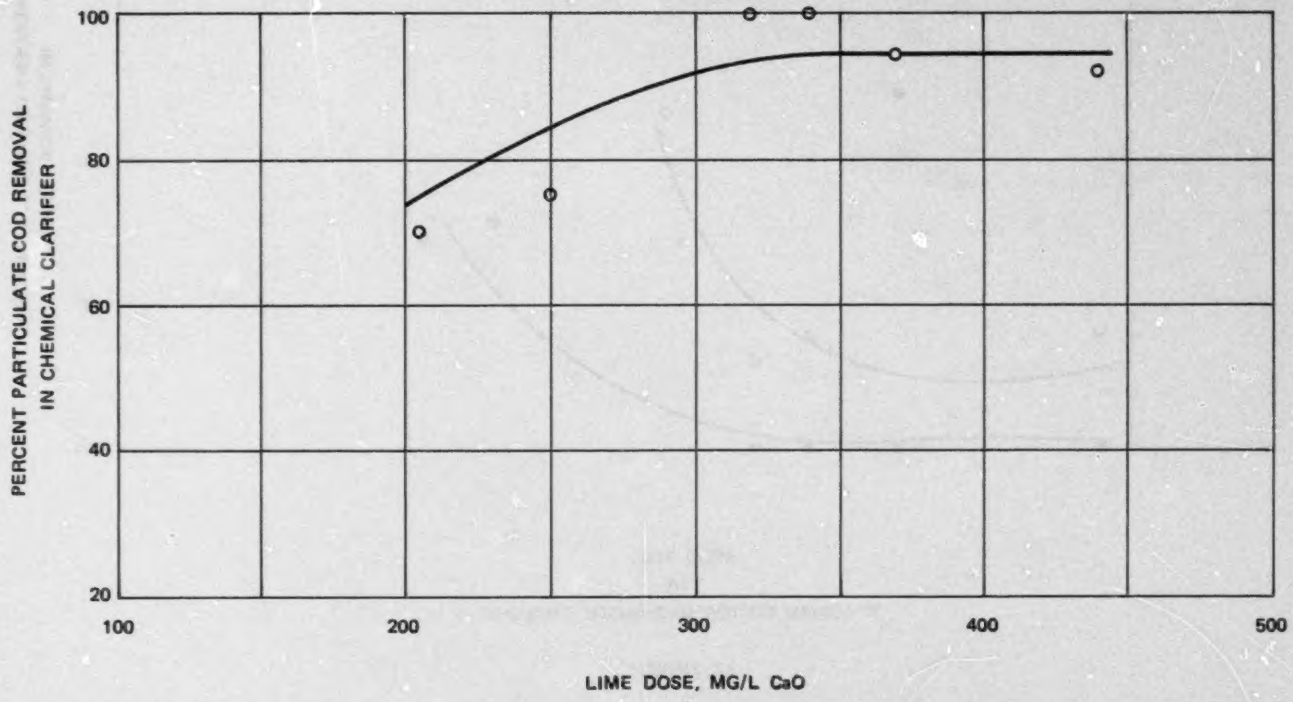


FIGURE 27

ORGANIC SUSPENDED SOLIDS REMOVAL
VS
LIME DOSE

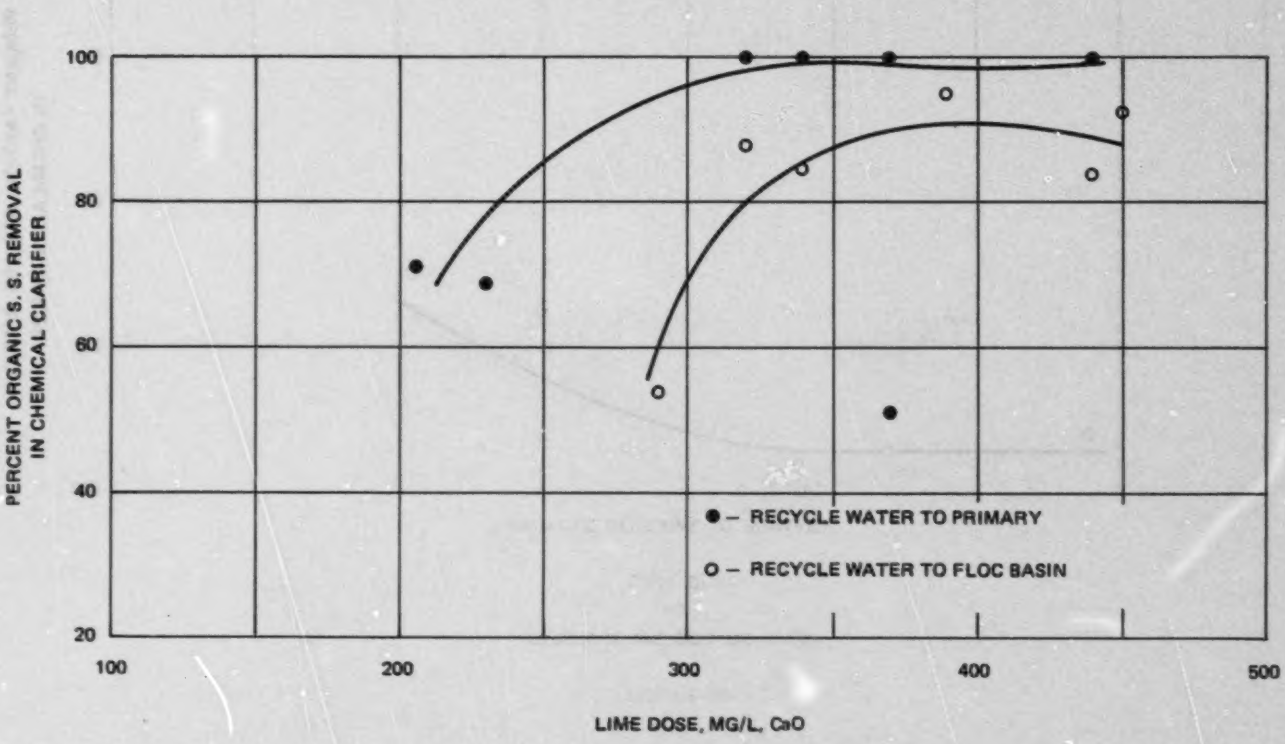
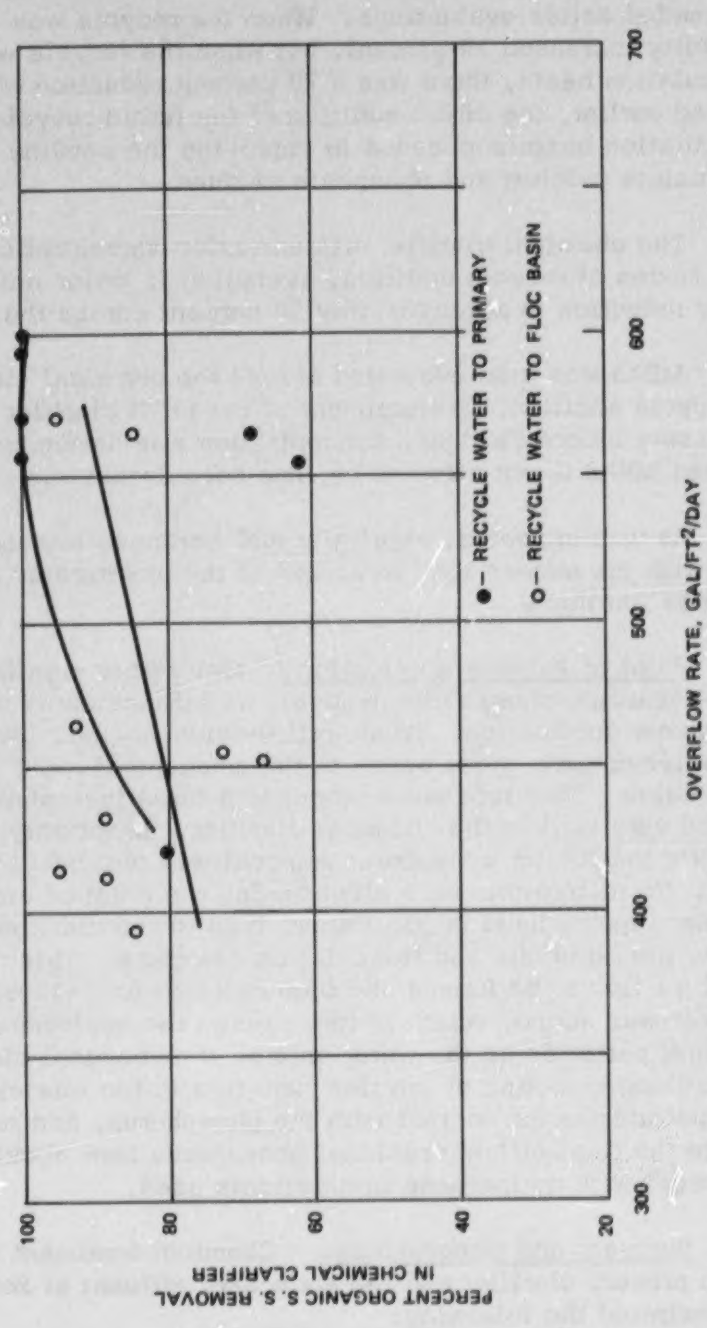


FIGURE 28

ORGANIC SUSPENDED SOLIDS REMOVAL

VS

CLARIFIER OVERFLOW RATE



pended solids with the recycle streams added to the primary and a 50 per cent removal of total suspended solids when recycle was added to the flocculation basin. Turbidity reductions correlated well with the untreated suspended solids evaluations. When the recycle was added to the primary, turbidity increased 20 percent, but when the recycle was added to the flocculation basin, there was a 70 percent reduction of turbidity. As discussed earlier, the direct addition of the turbid recycle streams to the flocculation basin succeeded in improving the settling characteristics of particulate calcium and phosphate sludges.

The chemical clarifier effluent color concentration was the same for both modes of recycle addition, averaging 12 color units. It appears the color reduction is approximately 50 percent across the clarifier.

MBAS was also evaluated across the chemical clarifier for both modes of recycle addition. Pretreatment of the pH 11 clarifier effluent to pH 7 was necessary before the MBAS concentration was determined. The results indicated MBAS is not affected by lime coagulation and clarification.

As was expected, alkalinity and hardness increased across the clarifier with the excess lime treatment of the unsaturated wastewater with respect to hardness.

Point of Polymer Application. One rather significant finding was made regarding phosphorus removal, as influenced by mixing and the point of polymer application. From April through August, 1968, both the lime and polymer were added ahead of the mechanical rapid mix and the flocculation basin. This procedure produced a large instantaneous floc which settled very well in the chemical clarifier. Laboratory jar tests indicated however that better phosphorus removal was obtained by smaller floc particles. To utilize this on a plant scale, the point of application of the polymer was changed in September, 1968 to the clarifier influent pipe following the rapid mix and flocculation chambers. This change allowed a fine lime floc to be formed and then agitated for 5-15 minutes before the polymer was added, which in turn caused the agglomeration of the floc into larger particles as the water entered the chemical clarifier for settling. The prolonged mixing of the fine lime floc in the wastewater provided greater opportunities for contact with the phosphorus, and resulted in a reduction in the final effluent residual phosphorus from about 0.7 mg/l to about 0.15 mg/l with no increase in chemicals used.

Summary and Conclusions. Chemical treatment with lime addition to the primary clarifier and the secondary effluent at South Lake Tahoe have demonstrated the following:

1. The addition of active lime to the primary clarifier resulted in a mixture of lime and organic sludge which proved to be very difficult and costly to dewater with a full scale centrifugal or a pilot vacuum filter.

2. During the period when lime was added to the primary clarifier, the pH averaged 9.3, with a range of 7.5 to 11.0 plus. Phosphorus removals averaged 20% and suspended solids removals 50%. During normal operation, without lime addition to the primary, phosphorus removals averaged 5% and suspended solids removals ranged from 50%-60%.

3. When lime was added to the primary, the activated sludge system continued to satisfactorily perform and produce a normal secondary effluent. The activated sludge mixed liquor had a considerable buffering capacity for the high pH primary effluent, reducing a pH of 11+ in the primary effluent-return sludge mixture to 8.5 within five feet of the aeration basin entrance.

4. The optimum lime dose for phosphorus removal from the secondary effluent per pound of lime at the South Tahoe Public Utility District plant is around 300 mg/l CaO. Only slightly greater removals are available at dosages up to 700 mg/l. The clarity of chemical clarifier effluent also reaches an optimum at around 300 mg/l.

5. During the study, the point of addition of the recycle waters had a noticeable affect on final effluent phosphorus concentrations. When the recycle waters were added to the floc basin, the final effluent PO_4-P concentration averaged from .07-.09 mg/l. More efficient clarification was attained with the turbid recycle waters added to the floc basin and hence better phosphorus removals.

6. Measurements of total and ortho phosphorus indicate practically all of the phosphorus in the secondary effluent is of the ortho form.

7. Clarifier overflow rates between 400 and 600 gal/day/ft^2 had no affect on phosphorus, BOD, COD, organic solids, or turbidity removals.

8. BOD removals averaged about 80% and COD removals averaged slightly less at 60%. Increasing lime doses provided better clarification and hence better total COD and BOD removals. Organic suspended solids removals from the secondary effluent average slightly less than 90%.

9. Soluble BOD and COD removals decreased with increasing lime dosages. It is felt that the high lime dosages converted portions of the organic particulates to soluble forms.

10. Color removals from the secondary effluent averaged about 50%.

11. Detergents, reported as MBAS, were not affected by lime coagulation.

12. Scale formation in the lime mud lines was easily removed by the routine use of a polyurethane pig with abrasive cutting edges.

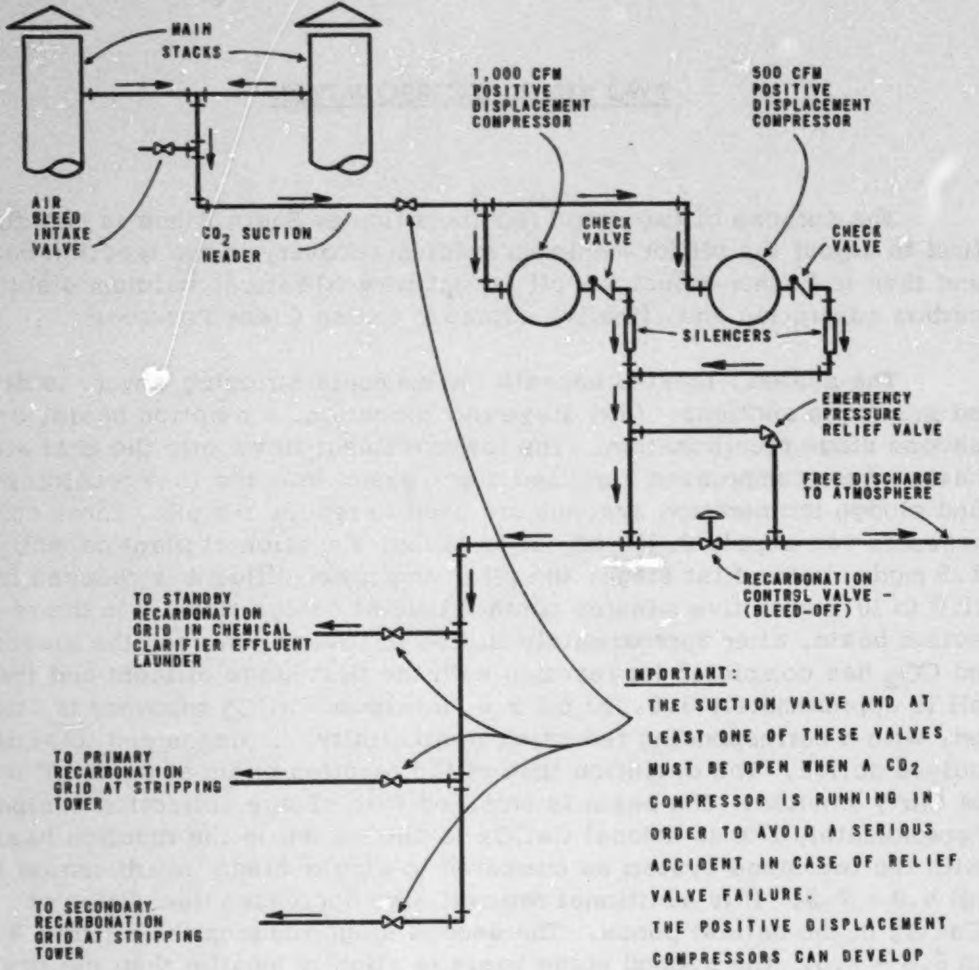
SECTION XVI

TWO STAGE RECARBONATION

The purpose of two stage recarbonation at South Tahoe is two-fold; first to adjust the pH for maximum calcium recovery in the reaction basin, and then to further adjust the pH for optimum filtration, calcium stability, carbon adsorption and, finally, export to Indian Creek Reservoir.

The system, located beneath the ammonia stripping tower, is divided into three sections; first stage recarbonation, a reaction basin, and second stage recarbonation. The tower effluent flows into the first stage basin where compressed scrubbed stack gases from the lime recalcining and sludge incineration systems are used to reduce the pH. Three compressors can supply 2,450 cfm at 6200 feet elevation at plant capacity of 7.5 mgd. In the first stage, the pH of the tower effluent is reduced from 11.0 to 10.3 with five minutes contact time at design flows. In the reaction basin, after approximately fifteen to twenty minutes, the dissolved CO_2 has completed its reaction with the first stage effluent and the pH is approximately 9.6. At pH 9.6, maximum $CaCO_3$ recovery is attained, with a corresponding reduction in alkalinity, hardness and total dissolved solids. The detention time of the reaction basin at design flows is thirty minutes. The basin is provided with sludge collection equipment. Approximately 17% additional $CaCO_3$ is settled out in the reaction basin with the two stage system as compared to single-stage recarbonation to pH 6.8 - 7.5. This additional removal also decreases deposition of $CaCO_3$ in the ballast ponds. The second stage reduces the pH from 9.6 to 6.8 - 7.5. The second stage basin is slightly smaller than the first, providing a 4-minute contact time at design flows.

Methods Used for Data Collection. Two methods of sampling were used to evaluate the efficiency of the two stage recarbonation system. For the first method, jar tests were performed to determine the pH level in the first stage effluent to achieve maximum calcium recovery, and to study the chemical composition of the water in the reaction basin. Secondly 24 hour composite samples were collected to evaluate on a plant scale reductions across the recarbonation system for alkalinity, chemical oxygen


MAIN
STACKS
1,000 CFM
POSITIVE
DISPLACEMENT
COMPRESSOR
500 CFM
POSITIVE
DISPLACEMENT
COMPRESSOR
AIR
BLEED
INTAKE
VALVE
CO_2 SUCTION
HEADER
CHECK
VALVE
CHECK
VALVE
SILENCERS
EMERGENCY
PRESSURE
RELIEF VALVE
FREE DISCHARGE
TO ATMOSPHERE
RECARBONATION
CONTROL VALVE -
(BLEED-OFF)
TO STANDBY
RECARBONATION
GRID IN CHEMICAL
CLARIFIER EFFLUENT
LAUNDER
TO PRIMARY
RECARBONATION
GRID AT STRIPPING
TOWER
TO SECONDARY
RECARBONATION
GRID AT STRIPPING
TOWER

IMPORTANT:
THE SUCTION VALVE AND AT LEAST ONE OF THESE VALVES MUST BE OPEN WHEN A CO_2 COMPRESSOR IS RUNNING IN ORDER TO AVOID A SERIOUS ACCIDENT IN CASE OF RELIEF VALVE FAILURE.
THE POSITIVE DISPLACEMENT COMPRESSORS CAN DEVELOP PRESSURES IN EXCESS OF THE BURSTING STRENGTH OF PIPE AND EQUIPMENT WHEN OPERATED AGAINST A CLOSED PIPELINE

FIGURE 29
RECARBONATION
SCHEMATIC

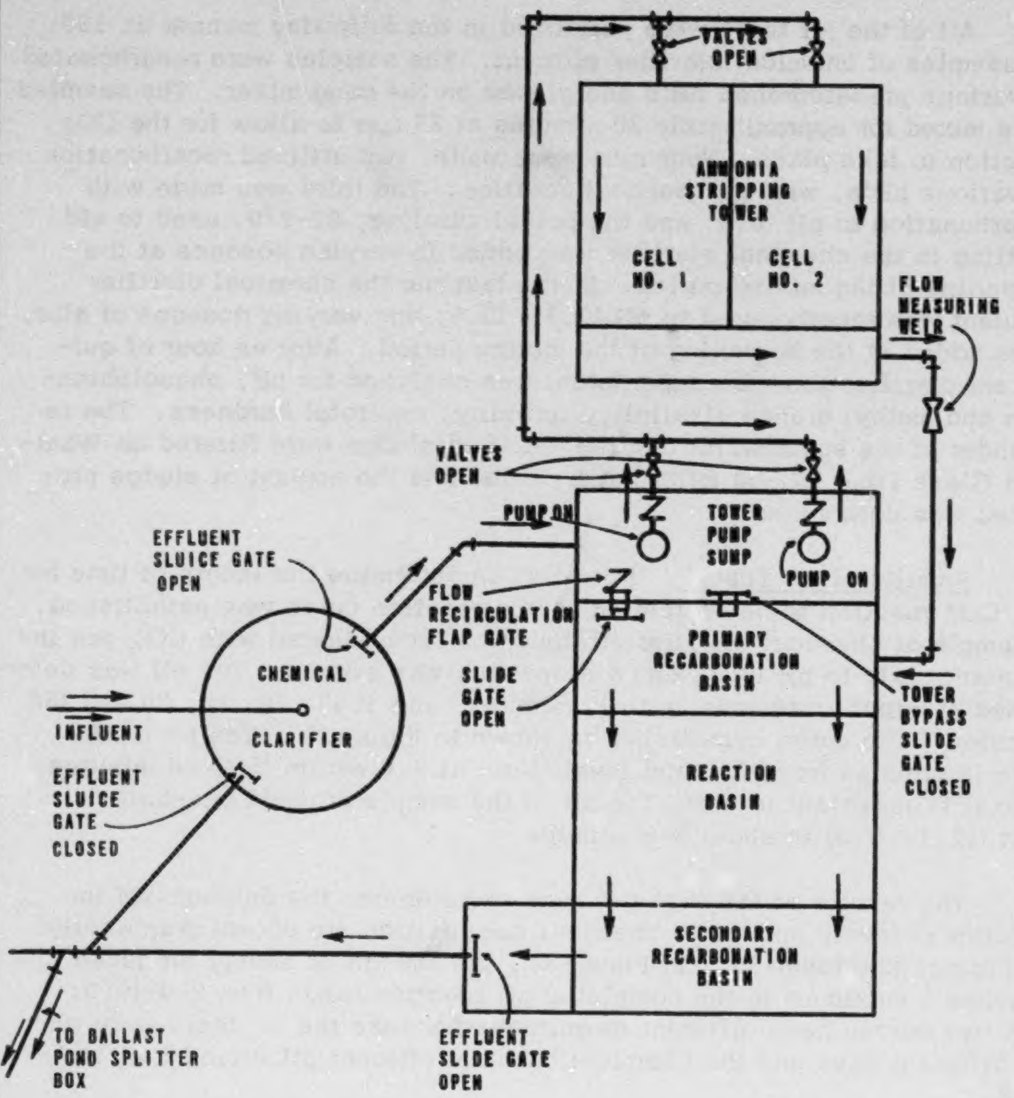

VALVES OPEN
AMMONIA STRIPPING TOWER
CELL NO. 1
CELL NO. 2
FLOW MEASURING WEIR
VALVES OPEN
PUMP ON
TOWER PUMP SUMP
PUMP ON
EFFLUENT SLUICE GATE OPEN
FLOW RECIRCULATION FLAP GATE
PRIMARY RECARBONATION BASIN
CHEMICAL
CLARIFIER
SLIDE GATE OPEN
TOWER BYPASS SLIDE GATE CLOSED
INFLUENT
EFFLUENT SLUICE GATE CLOSED
REACTION BASIN
SECONDARY RECARBONATION BASIN
TO BALLAST POND SPLITTER BOX
EFFLUENT SLIDE GATE OPEN

FIGURE 30
AMMONIA STRIPPING TOWER
AND RECARBONATION BASINS
NORMAL OPERATION

demand, phosphorus, total dissolved solids, suspended solids, turbidity, and total hardness.

All of the jar tests were performed in the following manner on 500 ml samples of chemical clarifier effluent. The samples were recarbonated to various predetermined pH's and placed on the gang mixer. The samples were mixed for approximately 30 minutes at 35 rpm to allow for the CO_2 reaction to take place. Four runs were made, two utilized recarbonation to various pH's, with no chemical addition. The third was made with recarbonation to pH 10.3, and the polyelectrolyte, ST-270, used to aid settling in the chemical clarifier was added in varying dosages at the beginning of the mixing period. In the last run the chemical clarifier effluent was recarbonated to pH 10.3 - 10.6, and varying dosages of alum were added at the beginning of the mixing period. After an hour of quiescent clarification, the supernatant was analyzed for pH, phenolphthalein and methyl orange alkalinity, turbidity, and total hardness. The remainder of the supernatant and the clarified sludge were filtered on Whatman Glass Fiber (GF/A) filter paper, dried and the amount of sludge produced was determined.

Results of Jar Tests. Initially, to determine the length of time for the CO_2 reaction to be completed, a CO_2 reaction curve was established. A sample of chemical clarifier effluent was recarbonated with CO_2 gas instantaneously to pH 10.3, and a stopwatch was started. The pH was determined at minute intervals up to 10 minutes, and at 15, 20, 25, 30 and 150 minutes. The curve established is shown in Figure 31 . The pH of the sample dropped from 10.3 and leveled out at 9.6 within 15 to 20 minutes. Also it is important to note, the pH of the sample dropped one-half unit (10.3 - 9.8) in about 5-6 minutes.

The results of the first two runs to determine the optimum pH for calcium recovery and water chemical composition are shown graphically in Figures 32 through 35 . In Figure 32 , the amount of sludge produced reaches a maximum in the completed pH reaction range from 9.4-10.0. The two curves have different magnitudes because the jar tests were run on different days and the chemical clarifier effluent pH varied from 11.5-11.8.

The chemical composition of the water also supports the best sludge production pH range of 9.4-9.9. A discussion of the wastewater hardness at South Tahoe is necessary before chemical composition and sludge production can be explained. At South Tahoe, calcium hardness as $CaCO_3$ constitutes the major portion of the total hardness, with only a small amount of magnesium hardness present. This has been verified in the

FIGURE 31

pH
VS
REACTION TIME
(Jar Test)

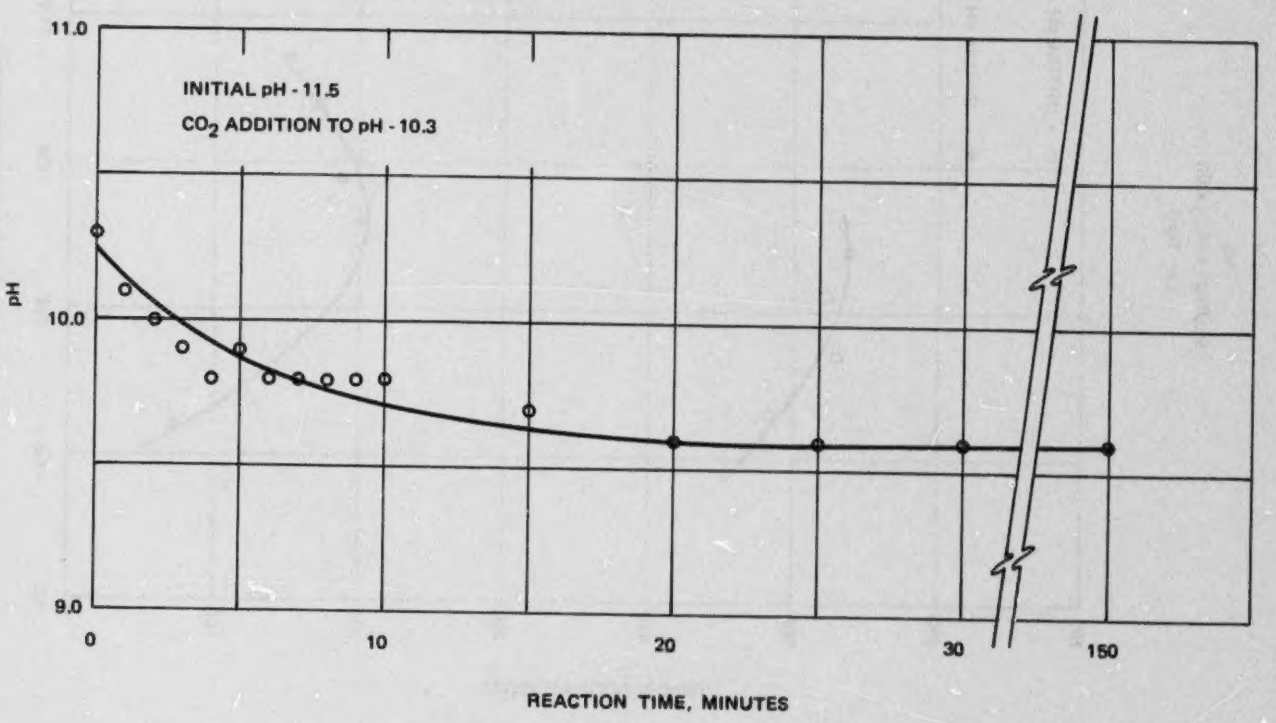


FIGURE 32

pH
VS
SLUDGE PRODUCED
(Jar Test)

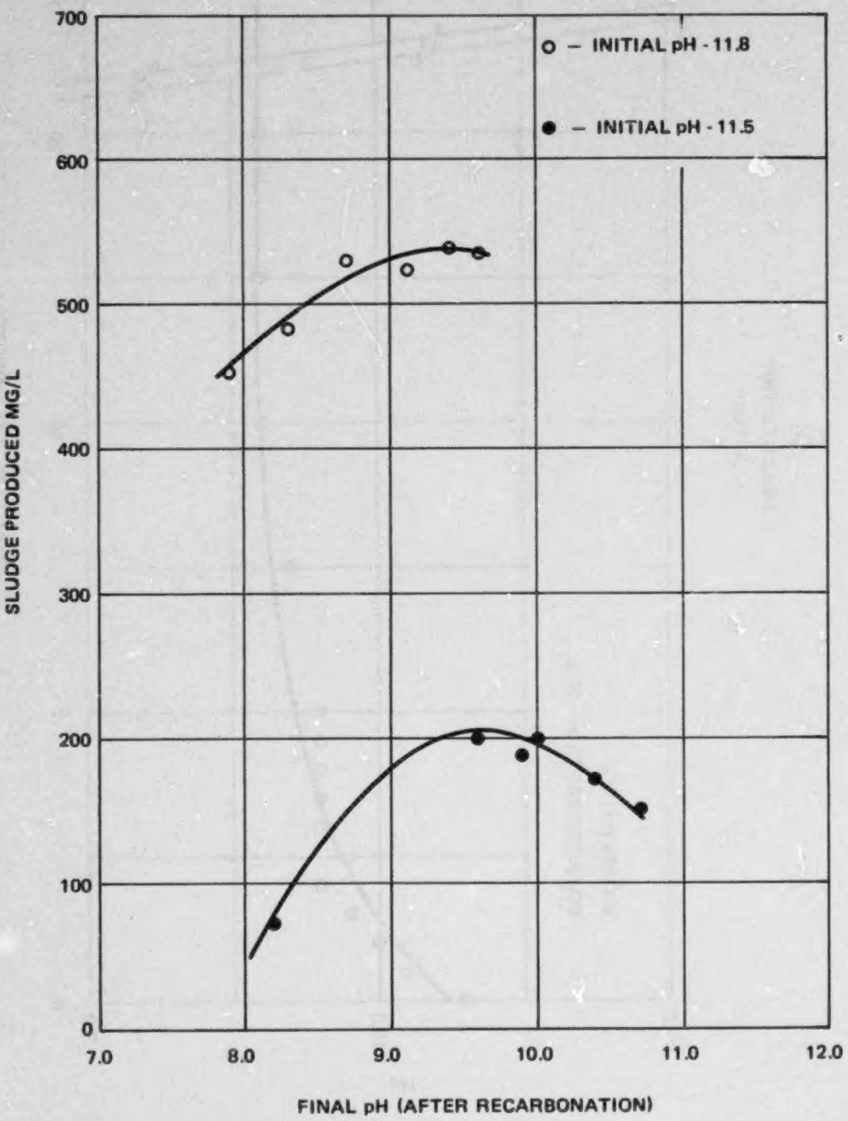


FIGURE 33

pH
VS
TOTAL HARDNESS
(Jar Test)

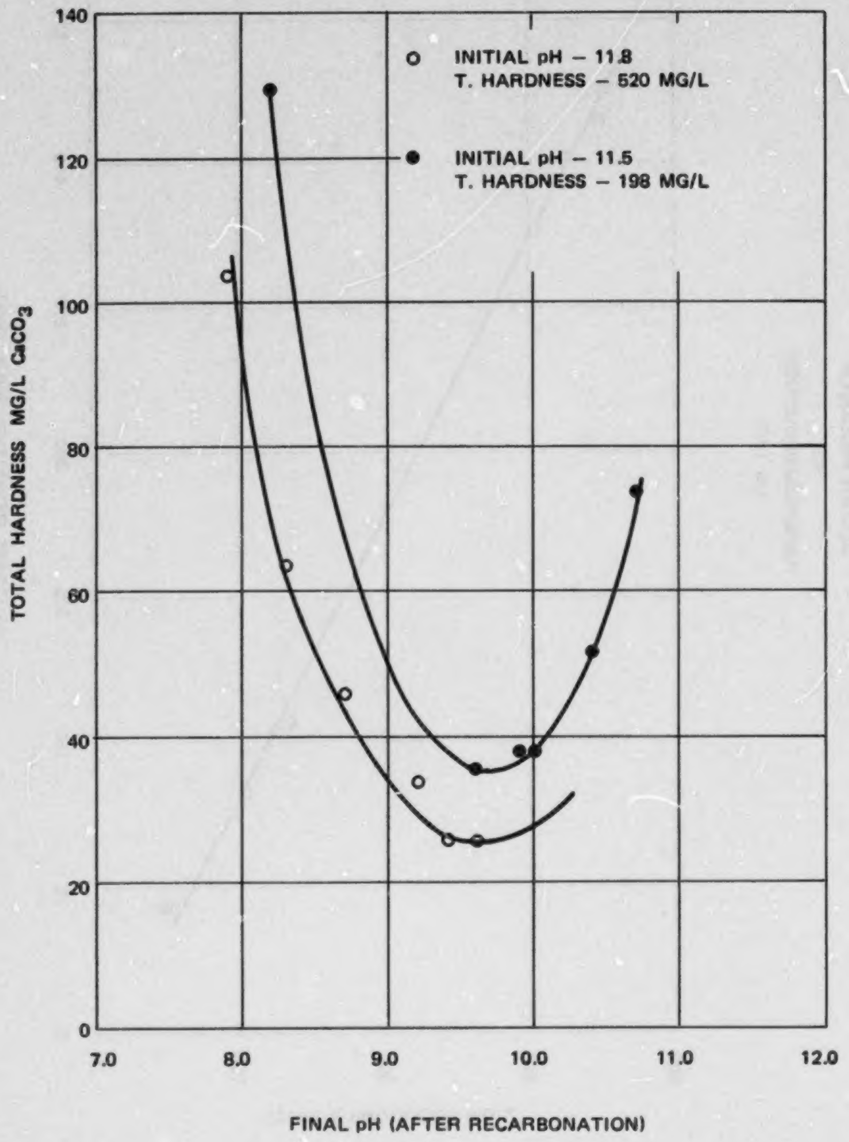


FIGURE 34

SLUDGE PRODUCED
VS
HARDNESS REDUCTION
(Jar Test)

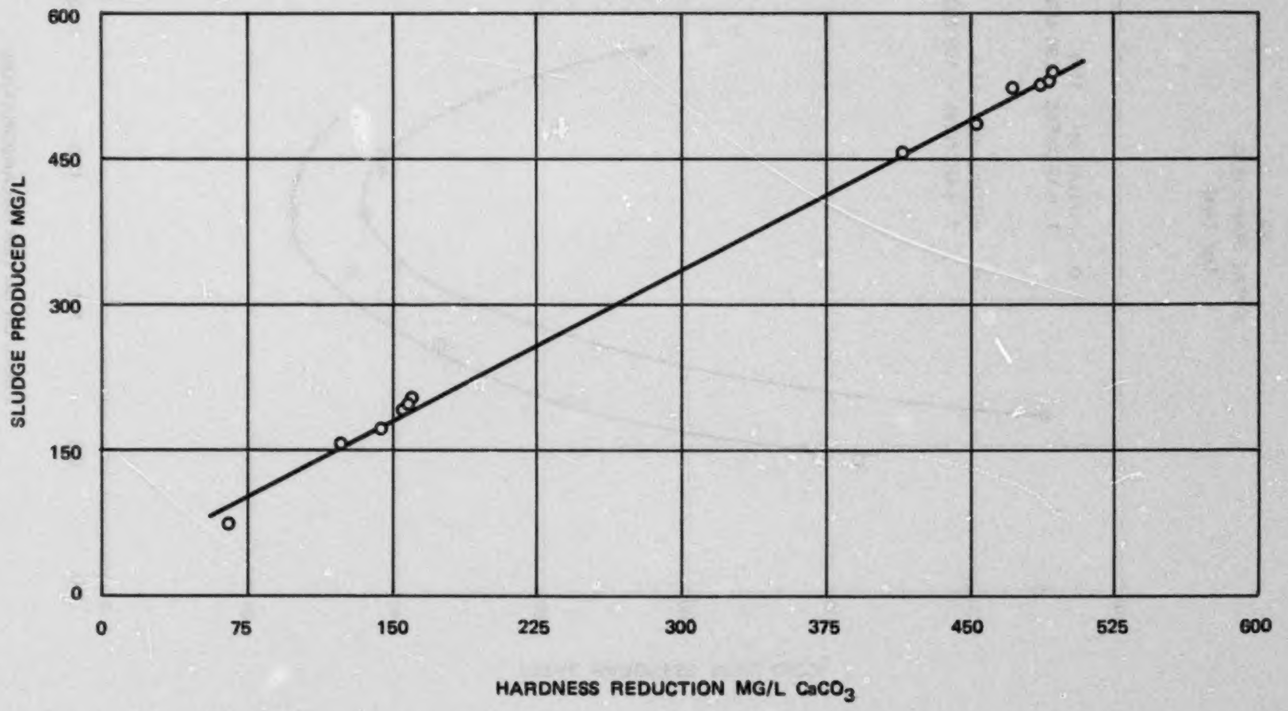
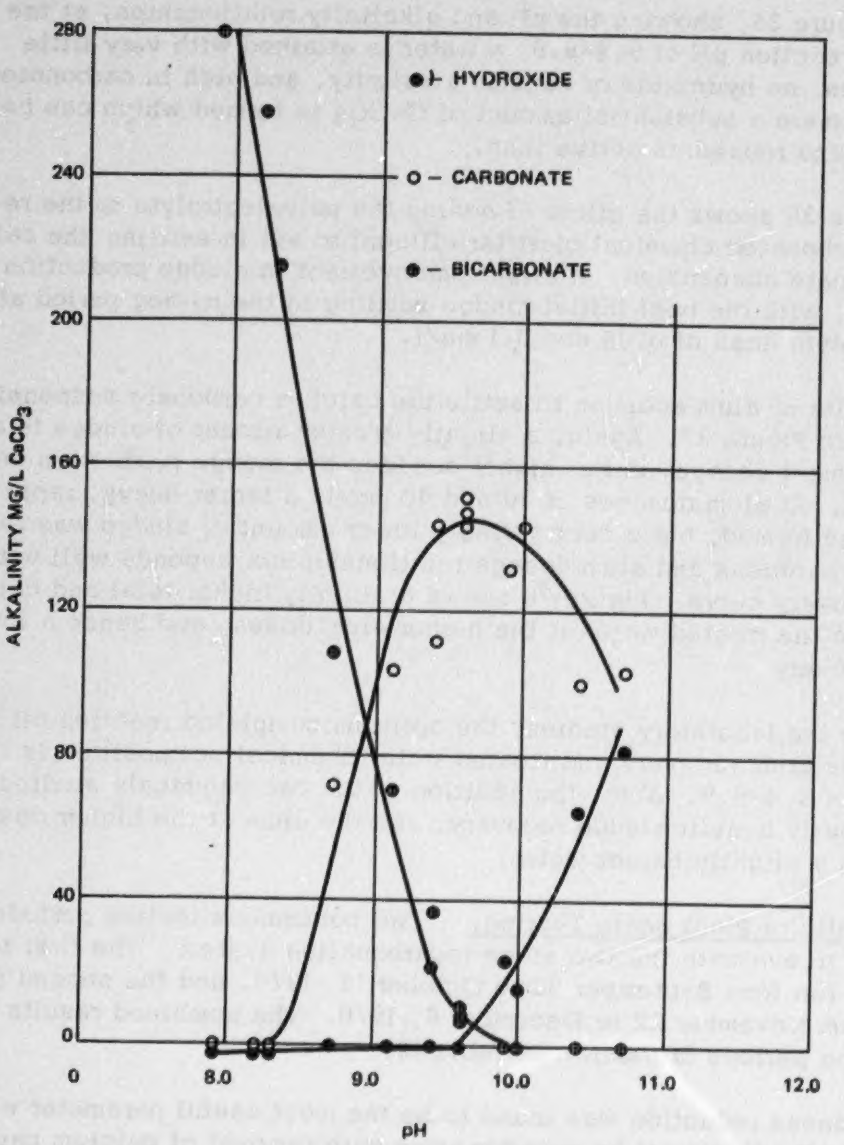


FIGURE 35

pH
VS
ALKALINITY
(Jar Test)



plant lab and at other private laboratories. In Figure 33, the pH and total hardness relationship, the minimum total hardness is attained around the completed reaction pH of approximately 9.4-9.6, and correspondingly, the minimum calcium hardness or maximum calcium recovery in the sludge. In Figure 34, a good correlation between sludge produced and total hardness reduction supports the above fact that the greater the total hardness or calcium reduction, the greater the amount of sludge produced.

In Figure 35, showing the pH and alkalinity relationships, at the completed reaction pH of 9.4-9.9, a water is attained with very little bicarbonates, no hydroxide or caustic alkalinity, and high in carbonates. At this pH range a substantial amount of $CaCO_3$ is formed which can be recalcined and reused as active lime.

Figure 36 shows the effect of adding the polyelectrolyte to the recently recarbonated chemical clarifier effluent to aid in settling the calcium carbonate suspension. A slight improvement in sludge production is attained, with the best initial sludge settling in the mixing period at polyelectrolyte dose of 0.05 and 0.1 mg/l.

Results of alum addition to settle the calcium carbonate suspension are shown in Figure 37. Again, a slightly greater amount of sludge is attained at 5-10 mg/l dosage, but at higher dosages the sludge production decreases slightly. At alum dosages of 30 and 40 mg/l, a larger heavy, rapid settling floc was formed, but a contrastingly lower amount of sludge was recovered. The hardness and alum dosage relationship corresponds well with the sludge recovery curve. Figure 38 shows a slightly higher total and calcium hardness in the treated water at the higher alum doses, and hence a lower sludge recovery.

From the laboratory studies, the optimum completed reaction pH for maximum calcium recovery and treated water chemical composition is in the range of 9.4-9.9. Also, the addition of the two chemicals studied did not greatly benefit sludge recovery, and the alum at the higher doses resulted in a slightly harder water.

Results of Plant Scale Testing. Two continuous testing periods were used to evaluate the two stage recarbonation system. The first testing period ran from September 30 to October 13, 1970, and the second period ran from November 22 to December 6, 1970. The combined results from both testing periods are shown in Table 13.

Hardness reduction was found to be the most useful parameter when comparing pH adjustment by recarbonation with removal of calcium carbon-

FIGURE 36

POLYELECTROLYTE DOSAGE
vs
SLUDGE PRODUCED
(Jar Test)

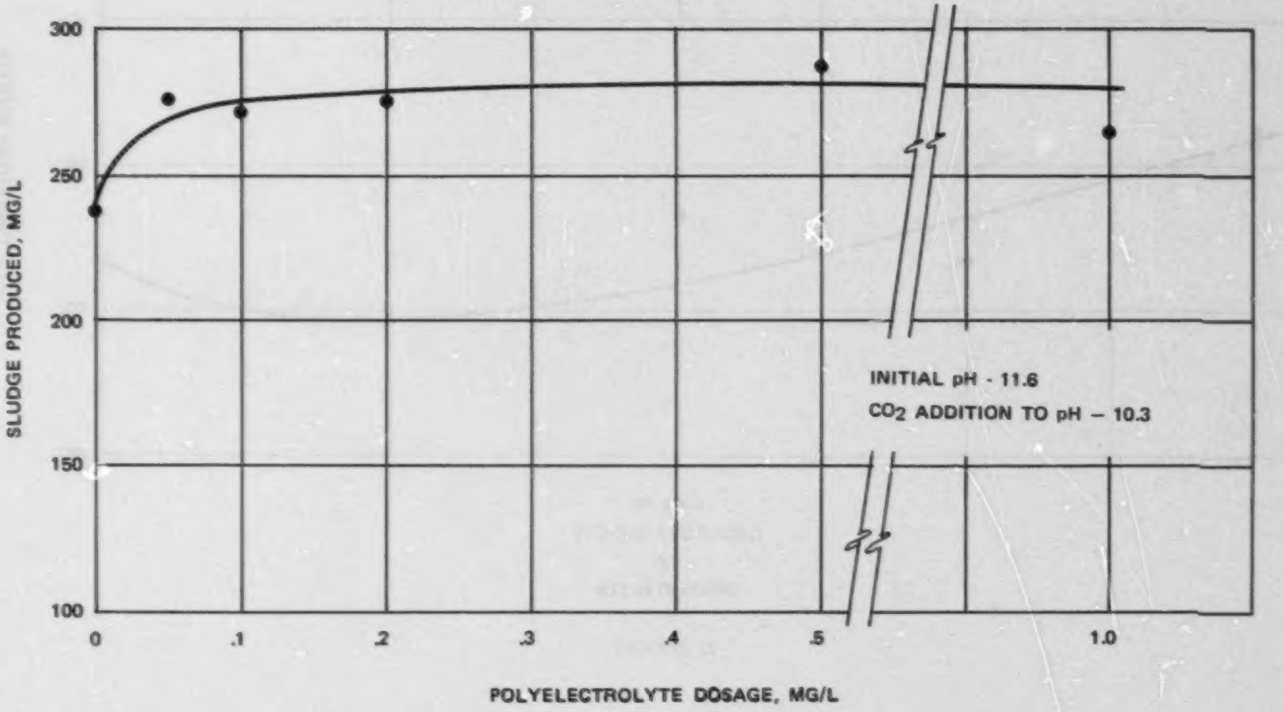


FIGURE 37

ALUM DOSAGE
VS
SLUDGE PRODUCED
(Jar Test)

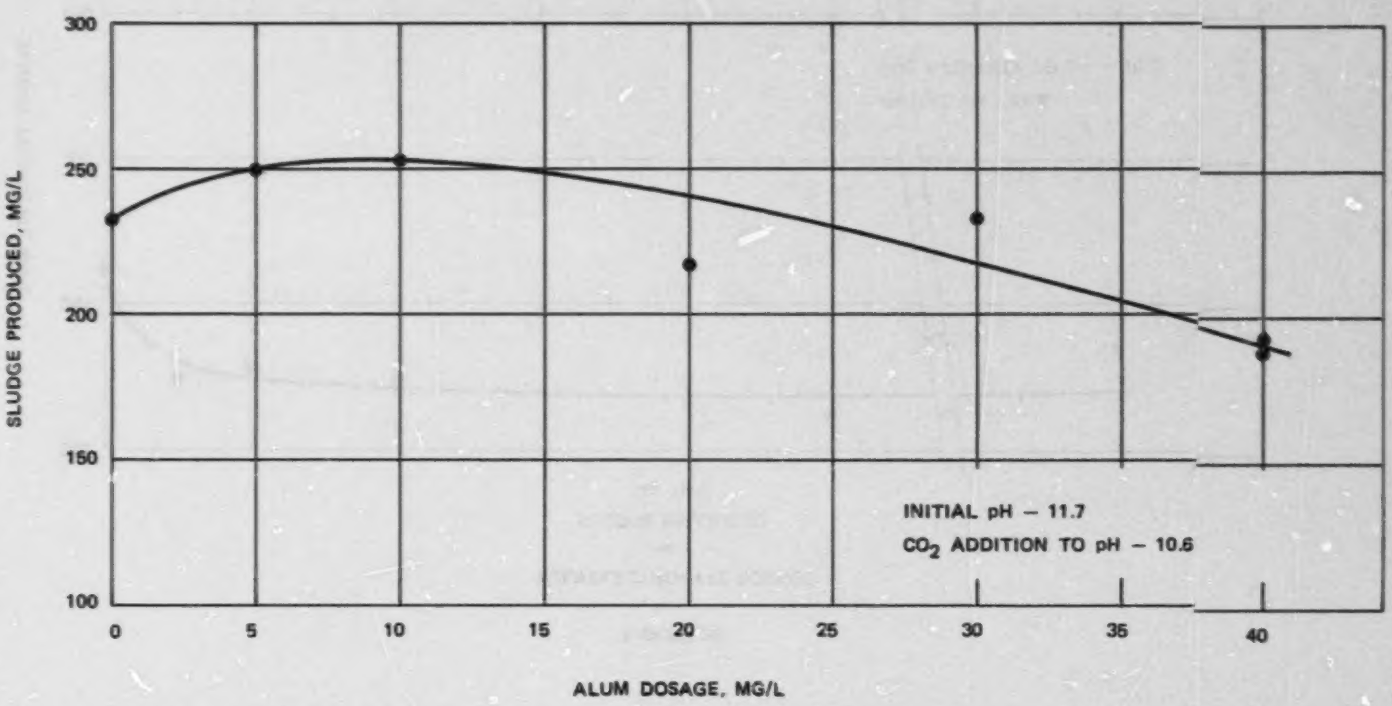


FIGURE 38

HARDNESS VS ALUM DOSAGE

(Jar Test)

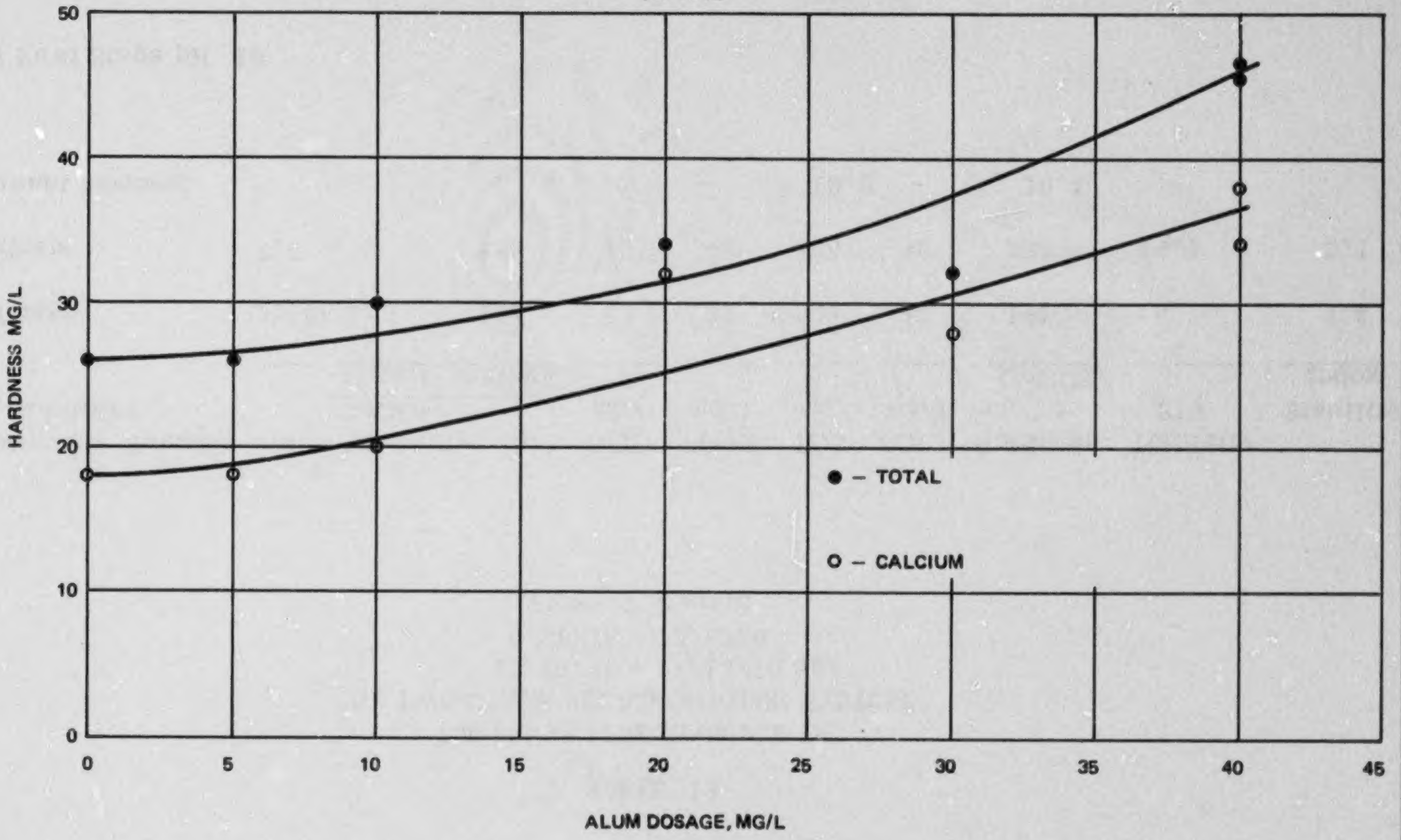


TABLE 13

AVERAGE PERFORMANCE OF THE TWO STAGE RECARBONATION SYSTEM

10/13/70 - 11/13/70 and
9/30/70 - 12/6/70
Flow: 2.85 mgd

Composite Samples 24 hours	pH	Alkalinity mg/l CaCO$_3$		COD mg/l	PO$_4$-P mg/l	TDS mg/l	S.S. mg/l	Hardness mg/l as CaCO$_3$	Turbidity SJU	Stability Index
		phenol	methyl							
Influent	11.1(1)	259	302	23	.33	323	21	191	6.7	3.6
Effluent	7.0	0	258	23	.43	288	49	133	14.3	8.1
Percent Removal			14.5	0	-	10.8	-	30.4	-	

(1) First Stage pH 10

ate in the reaction basin. Since full scale plant layout did not permit actual measurement of sludge volumes produced, the indirect method of comparing hardness reduction with sludge production (Figure 34) was used.

Depending on the first stage recarbonation pH, the hardness values in the second stage recarbonation effluent ranged between 102 and 174 mg/l as $CaCO_3$. The lowest hardness and indirectly the greatest sludge production was found to occur when the instantaneous pH in the first stage recarbonation effluent was kept between 10.1 and 10.6. Since at the South Tahoe Public Utility District there is normally about a 10-minute delay between sample collection and laboratory analysis, the best operating pH, in consideration of Figure 31, for the first stage recarbonation at South Tahoe was between 9.5 and 10.0.

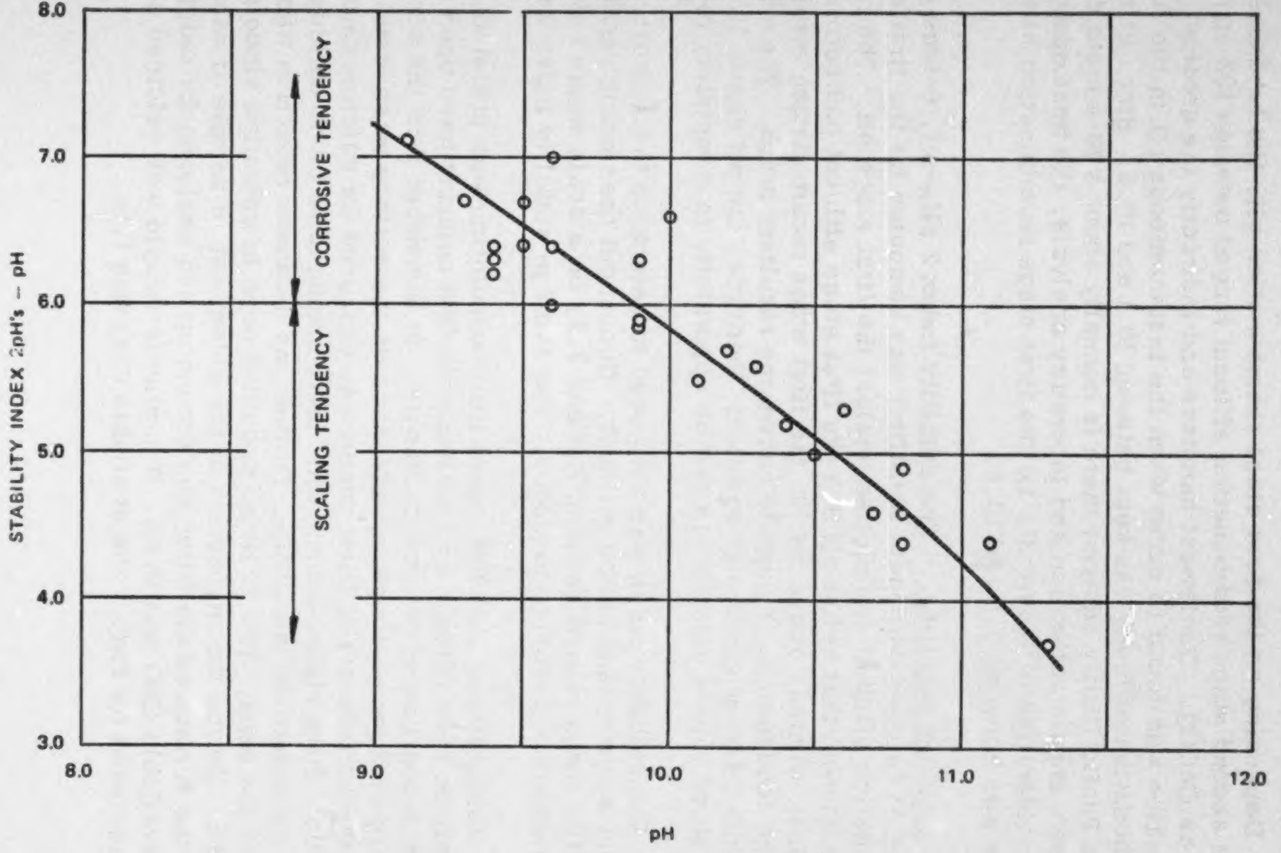
Calcium Stability. The stability index 2 pH_s-pH, (where pH_s = the pH at calcium carbonate stability) was computed for the first stage recarbonation effluent and plotted against the first stage pH. The resulting curve showed that below pH 9.5 the first stage effluent had corrosive tendencies; whereas above pH 10, the first stage recarbonation effluent had scaling tendencies. Figure 39 shows the resultant graph. The graph represents 24-hour composite samples; therefore, the pH shown is after the first stage carbon dioxide has had an opportunity to completely react.

The stability index was also used to determine the stability of the second stage recarbonation effluent. Throughout the testing period this stability index ranged between 7.3 and 9.2, on a scale where values above six indicate a corrosive tendency. The average stability index was 8.1.

Since March 31, 1968, when lime coagulation was initiated, the separation beds (filters) and activated carbon columns have been monitored for deposition of calcium carbonate. In November 1969 the six beds were opened for electrical maintenance on the surface wash arms. At this time the surface of the filter media was examined for calcium carbonate buildup. From visual examination there appeared to be no buildup of calcium carbonate on the media. Further, no hardness reduction was noted across the beds. Two of these beds had been in operation since the summer of 1966. During the inspection of the oldest set, a sample of sand and coal from the surface of the filter was ground up and analyzed for calcium oxide. The available CaO was 0.6%. A duplicate sample was calcined at 1800^{o}F and analyzed for CaO. The available CaO was 1.1%.

FIGURE 39

FIRST STAGE pH
VS
FIRST STAGE STABILITY INDEX



In nearly 3 years of operation there has been only one filter maintenance problem traceable to calcium carbonate scale buildup. This problem occurred in June of 1970. One of the 28 automatic butterfly valves connected with separation bed operations failed to function because of scale buildup. Inspection of the valve seat and piping to and from the valve showed a scale buildup of approximately 1/8 of an inch.

In October and November, 1970, carbon columns 1, 2, 3, 4, 5, 6 and 8 were inspected. No visual signs of calcium carbonate scale were observed on the vessel walls or influent and effluent screens. The inspection was accomplished by transferring all of the carbon from the column to be inspected to the empty reserve column. Further, no scale has ever been observed on the spent carbon since the beginning of lime coagulation treatment.

Desired pH Level. The desired pH level in the second stage recarbonation basin, in order to prevent deposition of calcium carbonate, was evaluated from September 1969 to November 1970. The monthly averages of the daily stability indices, taken from 24-hour composite samples, ranged between 7.1 and 8.2. The fourteen-month average was 7.6. Individual days were examined to determine an approximate relationship of pH with this stability index. The stability index was found to be below six for only one 24-hour composite sample in the fourteen months of study. The particular pH was 8.9 and the resulting stability index was 5.9. Generally speaking at pH values of 8.3 or above, the stability index was 6.1 to 6.2. Below a pH of 8.0, this index was above 7.

The calcium carbonate chemical balance or stability test (marble test) was performed on several occasions using the final effluent. This independent check indicated that the water was in equilibrium as to carbonate constituents.

Chemical Addition. Laboratory and plant scale tests were performed to determine the quantity of chemicals required to settle the suspension of calcium carbonate formed in the first stage recarbonation basin. Alum and a polymer, Calgon ST-270, were chosen for the evaluation.

The laboratory results as outlined earlier, showed that neither chemical significantly improved the capture of calcium carbonate.

No chemicals had been used in plant operation because good clarity was obtained in the effluent and therefore, the added expense of chemical addition was not justifiable. However, for the purposes of the grant, 10 mg/l of alum was added to the plant reaction basin just after the first stage recarbonation. Four days of 24-hour composite sampling showed no improvement in suspended solids or hardness reduction. The chemical addition was discontinued.

Summary and Conclusions. Studies of the two stange recarbonation system have demonstrated the following:

1. At current flows approximately 17% additional $CaCO_3$ is settled out in the reaction basin following the first stage of a two-stage recarbonation system. The additional recovery above that of a one-stage system provides a net cost savings of about $25/mg at current flows.

2. After first stage recarbonation with CO_2, 15-20 minutes is needed before the reaction is completed. The total pH drop after initial recarbonation is about 0.7 pH units. Seventy percent of the pH drop takes place in the first 5-6 minutes following recarbonation.

3. The best pH range for maximum sludge productions after first stage recarbonation and 15 to 20 minutes reaction time is 9.4 to 9.9. The optimum pH is 9.6. At the South Tahoe Public Utility District, where the pH of the first stage recarbonation effluent is normally read about 10 minutes after sample collection, the best pH range is 9.5 to 10.0.

4. In the laboratory a slight improvement of sludge production was noticed with addition of 0.05-0.1 mg/l of Calgon ST-270 or the addition of 5-10 mg/l alum. At plant scale no improvement in sludge production was observed when 10 mg/l of alum was added to the first stage recarbonation effluent. Until alum was used on plant scale no chemicals had been added to the reaction basin in 2 years of operation because it was felt that the effluent clarity and solids recovery was excellent and that the added chemical cost could not be justified.

5. The stability index on a scale of 1 to 14, with scaling tendencies below 6 and corrosive tendencies above 6, was used to estimate the desired pH level in the second stage recarbonation basin. It was found that pH values between 8.3 and 8.7 produced water which had slightly corrosive tendencies, according to the test. One 24-hour composite sample showed a very slight scaling tendency at pH 8.9. Below a pH of 8 in the secondary recarbonation effluent, the water showed definite corrosive tendencies. However, the marble tests of the finished water showed it to be stable.

6. For fourteen months of continuous 24-hour sampling, the monthly average of the daily stability indices ranged between 7.1 and 8.2. The fourteen month average was 7.6.

7. Inspection of the separation beds (filters) and the activated carbon columns after two to three years of continuous operation failed to disclose any visual signs of scale formation of any kind.

SECTION XVII

LIME RECOVERY AND REUSE

General. At a flow of 7.5 mgd through the water reclamation plant approximately 17 tons (dry CaO basis) per day of lime mud would have to be dewatered and disposed of. Since about 93% by weight of this lime mud is in the form of calcium carbonate , disposal costs would include not only dewatering and disposing of about 34 tons of water and solids but also the loss of recoverable calcium oxide. By recovering the lime through recalcination, the total blow-down of waste solids is reduced to about 1.5 tons of dry solids. The cost of recalcined lime as shown later would be slightly more than that of new lime at 7.5 mgd; however, at this flow the reuse of lime reduces by a factor of 20 the amount of water and sludge to be disposed of and, therefore, effects a substantial cost savings.

Physical System. Lime mud is pumped from the chemical clarifier and recarbonation reaction basin to a 30-foot diameter gravity thickener, with a design overflow rate of 1000 gal/ft^2/day. Thickened lime mud is pumped to a 24" x 60" solid bowl concurrent flow centrifuge. The cake from the centrifuge is carried by a belt conveyor to a 14.3 foot diameter, six hearth furnace in which calcium oxide and carbon dioxide are produced. The recalcined lime is conveyed out of the furnace by gravity through a crusher to a thermal disc cooler where lime temperatures are lowered from 700^{o}F to 100^{o}-150^{o}F, and then into a rotary air lock. The recalcined lime is pneumatically conveyed from the rotary air lock to a 35-ton capacity recalcined lime storage bin for eventual reuse. Stack gases, rich in carbon dioxide, are scrubbed in a multiple tray scrubber before being exhausted to the atmosphere. A portion of the gases are recycled to the recarbonation system. See Figure 41.

Solids wasting must be performed continuously to maintain an acceptable calcium oxide content in the recalcined lime. Wasting can be accomplished by feeding recovered lime to the primary clarifier, by diverting part of thickener influent to the primary clarifier, by conveying lime mud cake from the centrifuge directly to the organic sludge furnace or by using the centrifuge to classify the phosphate and other inerts into the centrate and the calcium carbonate into the dewatered cake conveyed to the

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NOT REPRODUCIBLE

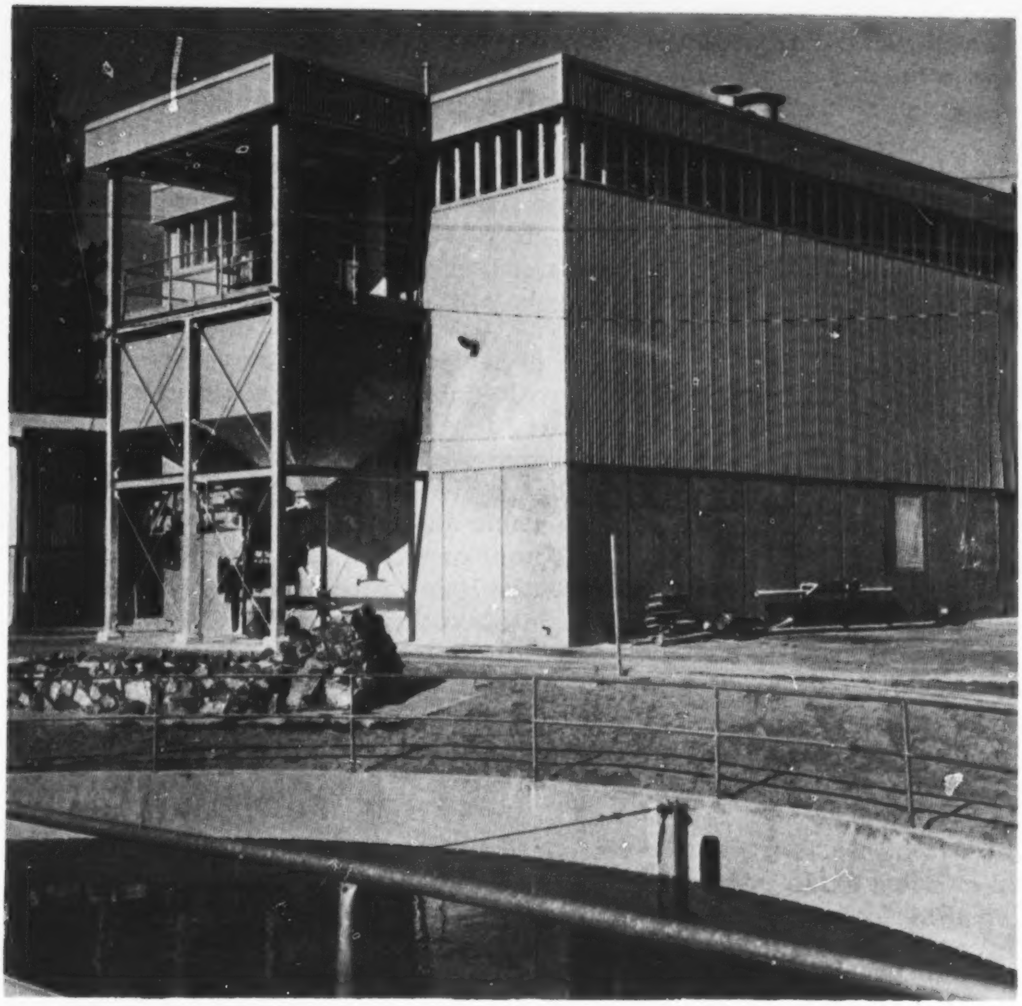


Figure 40

SOLIDS HANDLING BUILDING

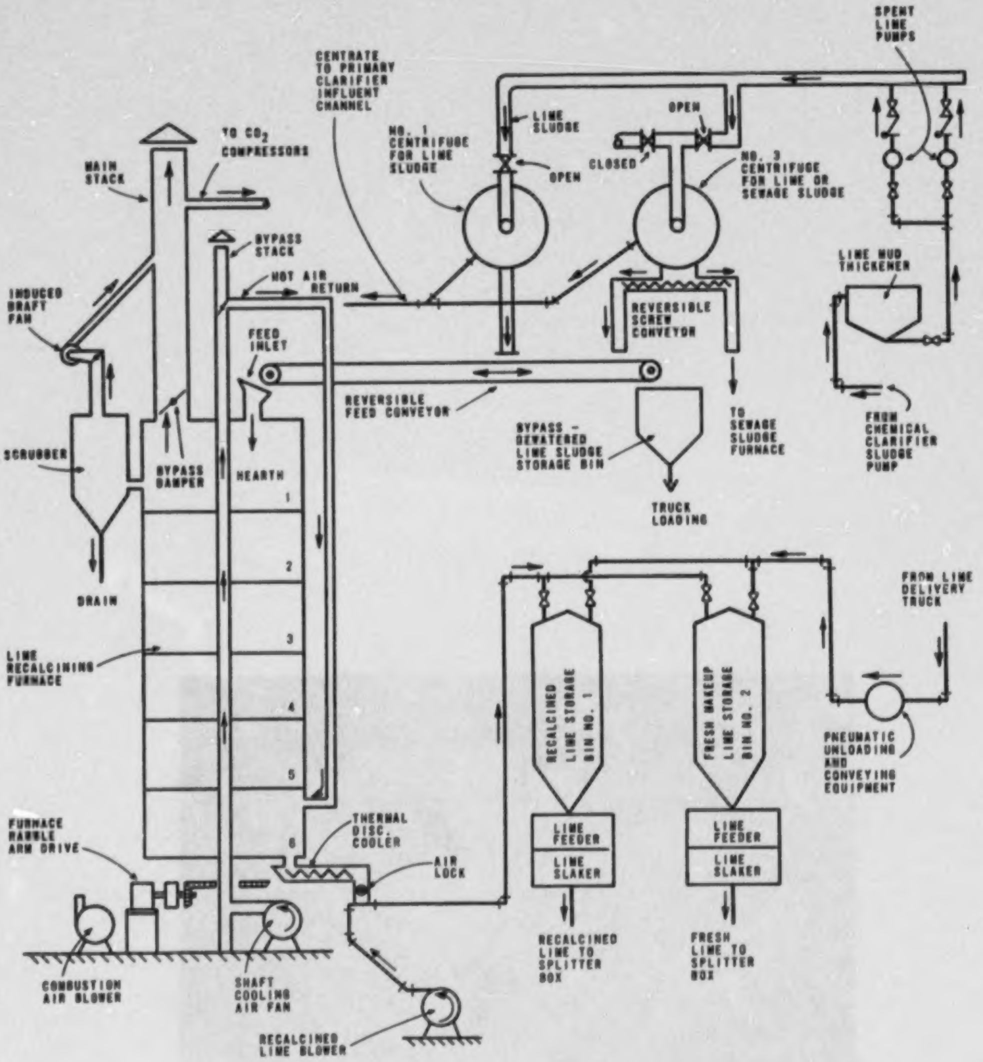

CENTRATE TO PRIMARY CLARIFIER INFLUENT CHANNEL
SPENT LIME PUMPS
LIME SLUDGE
OPEN
NO. 1 CENTRIFUGE FOR LIME SLUDGE
OPEN
CLOSED
NO. 3 CENTRIFUGE FOR LIME OR SEWAGE SLUDGE
TO CO_2 COMPRESSORS
MAIN STACK
BYPASS STACK
HOT AIR RETURN
INDUCED DRAFT FAN
LIME MUD THICKENER
REVERSIBLE SCREW CONVEYOR
FEED INLET
REVERSIBLE FEED CONVEYOR
BYPASS - DEWATERED LIME SLUDGE STORAGE BIN
TO SEWAGE SLUDGE FURNACE
FROM CHEMICAL CLARIFIER SLUDGE PUMP
SCRUBBER
BYPASS DAMPER
HEARTH
1
2
3
4
5
6
TRUCK LOADING
DRAIN
FROM LIME DELIVERY TRUCK
LIME RECALCINING FURNACE
RECALCINED LIME STORAGE BIN NO. 1
FRESH MAKEUP LIME STORAGE BIN NO. 2
PNEUMATIC UNLOADING AND CONVEYING EQUIPMENT
FURNACE RABBLE ARM DRIVE
THERMAL DISC. COOLER
AIR LOCK
LIME FEEDER
LIME SLAKER
LIME FEEDER
LIME SLAKER
RECALCINED LIME TO SPLITTER BOX
FRESH LIME TO SPLITTER BOX
COMBUSTION AIR BLOWER
SHAFT COOLING AIR FAN
RECALCINED LIME BLOWER

FIGURE 41
SOLIDS HANDLING
LIME SLUDGE

NOT REPRODUCIBLE

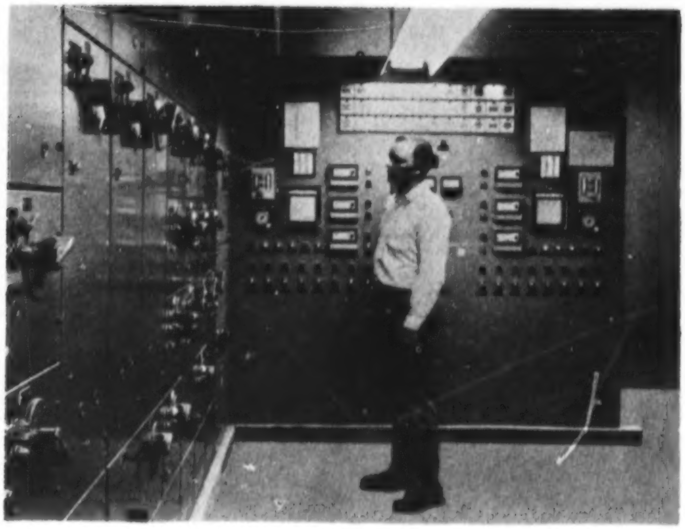


Figure 42

FURNACE CONTROL PANEL

recalciner. A second centrifuge dewaters the centrate from the first machine and its cake is conveyed to the organic sludge furnace.

The centrate from the lead centrifuge may be returned to the primary clarifier instead of directed to the second machine. The second centrifuge's centrate is returned to the primary. The spillage from the lime conveyor belt is collected in a tray and returned to either the primary clarifier or to the lime mud thickener.

Operating Practice. Since plant startup in 1968, steps have been taken to remove all active lime or waste lime mud streams from the primary clarifier. As described in the "Chemical Treatment" section, feeding active lime to the primary clarifier led to organic sludge dewatering problems and to some extent adversely affected primary clarification. Waste lime mud streams being returned to the primary clarifier also affected, but to a lesser extent, the dewatering characteristics of the raw and waste activated sludges.

In January, April and May 1970, and from July 1970 to date, the lime centrifuge has been used to classify inert materials out of the feed to the recalcining furnace. At the same time, the classified centrate from the first centrifuge has been dewatered and clarified in a second centrifuge and dried in the organic incineration furnace. The degree of classification and resulting economies are discussed later in this section.

Lime Mud Thickening. Total solids tests were used to evaluate the efficiency of the lime mud thickener. To determine the amount of calcium lost over the thickener launder the following procedures were used. Basin overflows and sludge withdrawals were measured to determine the influent flow. The amount of calcium in the thickener influent was determined by heating the influent total solids samples in the laboratory muffle furnace at 1850°F for two hours and then determining the available CaO content. By this method, the calcium hydroxyapatite, $Ca_5OH(PO_4)3$, was not included, and the value reflected only the calcium in $CaCO_3$ and $Ca(OH)2$. Part of the influent sample was filtered 0.45 u millipore filter and calcium hardness was run on the filtrate to determine the $Ca(OH)_2$. The difference in the two provided the pounds of usable calcium available for thickening.

The pounds of usable calcium in the thickener overflow were found by determining the difference in calcium content between acidified and filtered samples.

The amount of usable calcium lost over the thickener launder was evaluated over an eight hour composite sampling period. Using the procedures described above, 0.04% by weight of the usable calcium coming into the thickener was lost over the weir.

The true ability of the thickener to concentrate lime mud solids could not be evaluated due to low plant flows. Thickener influent percent solids were about 1% by weight. At chemical clarifier flows of 2.8 mgd and thickener underflow rates of 36 gpm, the lime mud was thickened to 4.9% solids; whereas at 3.7 mgd through the chemical clarifier and 15 gpm thickener underflow rate, lime mud was thickened to 8.3% solids.

Lime Mud Classification and Dewatering. During the lime centrifuge acceptance tests, three bowl speeds were evaluated to determine the optimum centrifugal bowl speed. The three bowl speeds evaluated were 1600, 1800, and 2200 rpm. Each of the three evaluations were conducted at 140:1 gear reduction ratio. The function of the gear unit is to drive the conveyor at a fixed speed relative to the bowl. For the three bowl speeds above, the conveyor revolved at approximately 11.5, 13, and 15.5 rpm. For all three bowl speeds evaluated, the cake solids ranged from 36-38%, and recovery or capture remained fairly constant. As a result, the lowest bowl speed of 1600 rpm was chosen for plant operations because of the reduced wear and maintenance problems.

Chemical Addition. Since the lime centrifuge is used primarily for classification purposes and not dewatering, polyelectrolytes were not used to condition the thickened mud prior to centrifuging. In the next section the excellent classification results are discussed. The addition of a polyelectrolyte to the centrifuge feed would defeat these purposes.

Classification Evaluation. Two methods were used to evaluate the centrifugal classification of the inert calcium hydroxyapatite out of the lime solids recovery stream. The first was to make four, ten-minute sampling runs with high and low feed rates and pool depths within the centrifuge to optimize the classification process. An approximate twenty minute interval was allowed after making adjustments to the centrifuge to insure steady state conditions for a particular set of variables. The centrifuge bowl speed was kept constant at 1600 rpm. During each ten-minute period a sample was composited uniformly on the feed, centrate, and cake steams. The centrifuge pool depth, cake volumetric flow rate and wet density, and centrate flow rate were recorded. The composited samples were analyzed for total solids and then calcined in a muffle furnace at 1750°F. The total solids, percent capture and centrate flow rate were used to compute the feed rate. After calcination, the samples were analyzed for CaO, and samples were dissolved in acid and analyzed for magnesium and orthophosphates.

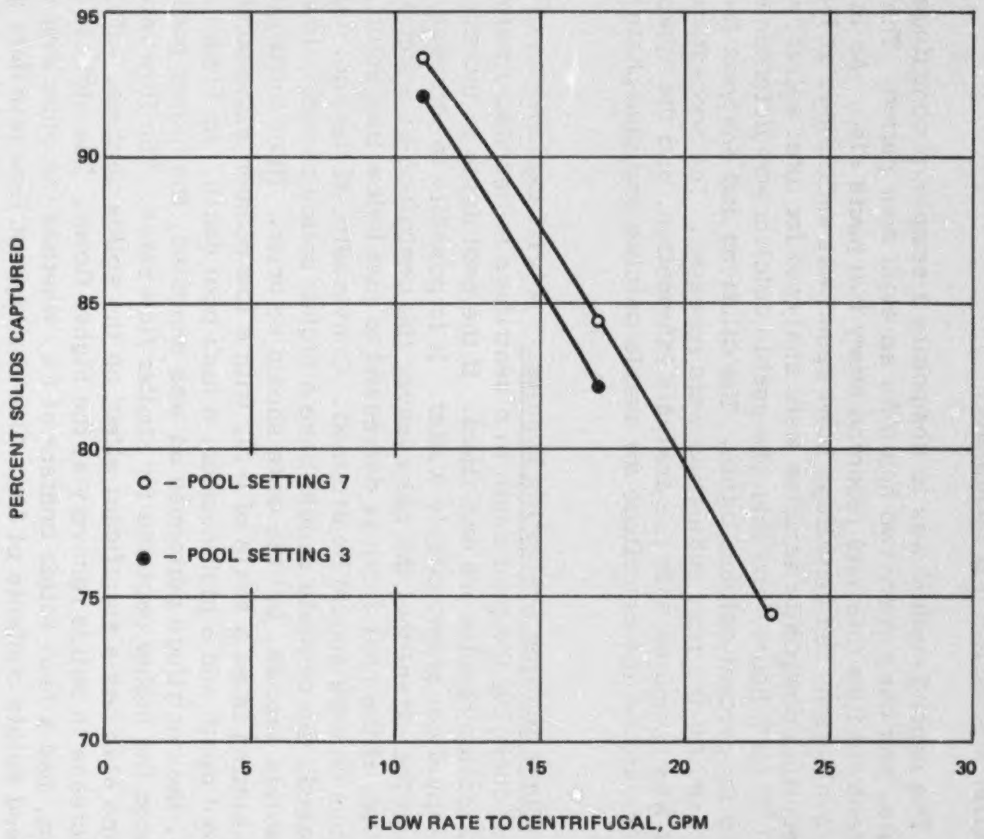
With the volumetric flow rate and phosphate and calcium results, balances were made around the centifuge for usable calcium, and the inert materials, magnesium and phosphate.

The second method was to composite a sample of centrifuge feed, centrate, and cake every two hours for an eight hour period. The centrifuge centrate flow rate was recorded every two hours also. As in the previous evaluation, the centrifuge bowl speed was maintained at 1600 rpm. The resulting composite samples were analyzed for total solids, calcined at 1750°F for 2 hours, and then the usable calcium was determined by analyzing for percent calcium oxide. The dilutions and analysis for phosphate used for the first evaluation were repeated. The percent capture for solids was computed with the analysis information, and the appropriate balances around the centrifuge for usable calcium and phosphate were determined.

Classification Evaluation Results. A brief explanation of the effects of changing the pool depth in a centrifuge is necessary before the classification results are explained. If the pool depth is increased, the cake should get progressively wetter. It is possible to increase the pool depth to the extent that the cake leaves the centrifuge as a wet slurry. However, if the pool depth is decreased to just below this point, the maximum capture should be attained. Conversely, if the pool depth is decreased, the centrate should have a higher solids content, lower percent solids capture, but the cake should be drier. The centrifuge pool depth setting is on a scale of 1-10, with a low number corresponding to a low pool depth and a high number, a high pool depth. As Figure 43 indicates, the centrifuge performed as was expected, the higher pool depth produced the higher captures for similar flow rates. The flow rate to the machine also has a significant effect on the solids capture, with a marked decrease in solids recovery at the higher flows. The highest flow rate, 23 gpm, had a feed solids content of 6%, whereas the other four data points had feed solids contents of 8%. Also the highest flow rate data point was derived from an eight-hour sampling period, and the other four points were from ten minute sampling periods.

FIGURE 43

PERCENT SOLIDS CAPTURED VS FLOW RATE TO CENTRIFUGAL



The removal of inert materials by classification into the centrate stream provides many benefits to the lime treatment and solids recovery system. A significant savings in fuel usage is realized, which is described later in the recalcining portion of this section. Also the size of the waste stream is reduced, a smaller amount of usable lime is lost, which results in lower makeup lime dosage and costs. The effect of solids capture or recovery in the centrifuge on the removal of inert materials from the feed to the recalcination furnace by classification is shown in Figures 44 through 47. The data in Figures 44 and 45 is derived from the two previous sampling runs described and from three runs of the optimization of the recalcination furnace described later. As would be expected, higher captures of solids from the centrifugal feed will result in a lower percent increase in the usable calcium or active lime, CaO, in the cake. At lower captures the lower specific gravity inert materials can be separated from the usable lime. This is very evident in Figure 44, at 90% solids capture there is only a 5% improvement in the percent CaO of cake over the feed to the centrifugal. At 70-75% solids capture, a 12-15% improvement in the cake percent CaO over the centrifugal feed can be expected. Correspondingly in Figure 45, at 95% capture practically all of the usable calcium is conveyed to the recalcination furnace, but so are a majority of the inert materials. At lower solids recoveries a portion of the usable calcium is lost in the centrate, but the higher active lime or CaO content of the cake from better classification of the inerts more than offsets this loss.

Since one of the high priorities of the treatment at South Tahoe is to remove phosphorus from the wastewater, the logical question is how efficient is the phosphorus removal from the lime solids recovery stream. In Figure 46, the effect is shown of solids capture and classification on the amount of phosphate wasted in the centrate. The four data points above 80% capture are taken from the ten-minute sampling periods and the other point is taken from the eight-hour period. At 90% capture or 10% of the solids entering the centrifuge being removed in the centrate, a 20% reduction in phosphate in the cake can be expected. A centrate containing 20% of the solids entering the centrifuge will have almost 40% of the phosphate entering the centrifugal. According to the trend indicated in Figure 46, 90% of the phosphates in the centrifuge feed can be wasted to the centrate at 75% solids capture or recovery, which corresponds well with Figure 44, indicating a near maximum increase in the cake CaO over the centrifuge feed CaO around 75% capture of solids. The removal of magnesium from the centrifuge feed to the centrate by classification is shown in Figure 47. The four data points shown in Figure 47, are from the ten-minute sampling runs; magnesium was not analyzed in the eight-hour run. The fourth point in Figure 47 was disregarded in drawing the

FIGURE 44

EFFECT OF CENTRIFUGAL CAPTURE ON THE CHANGE IN CALCIUM OXIDE CONTENT OF THE CENTRIFUGAL CAKE

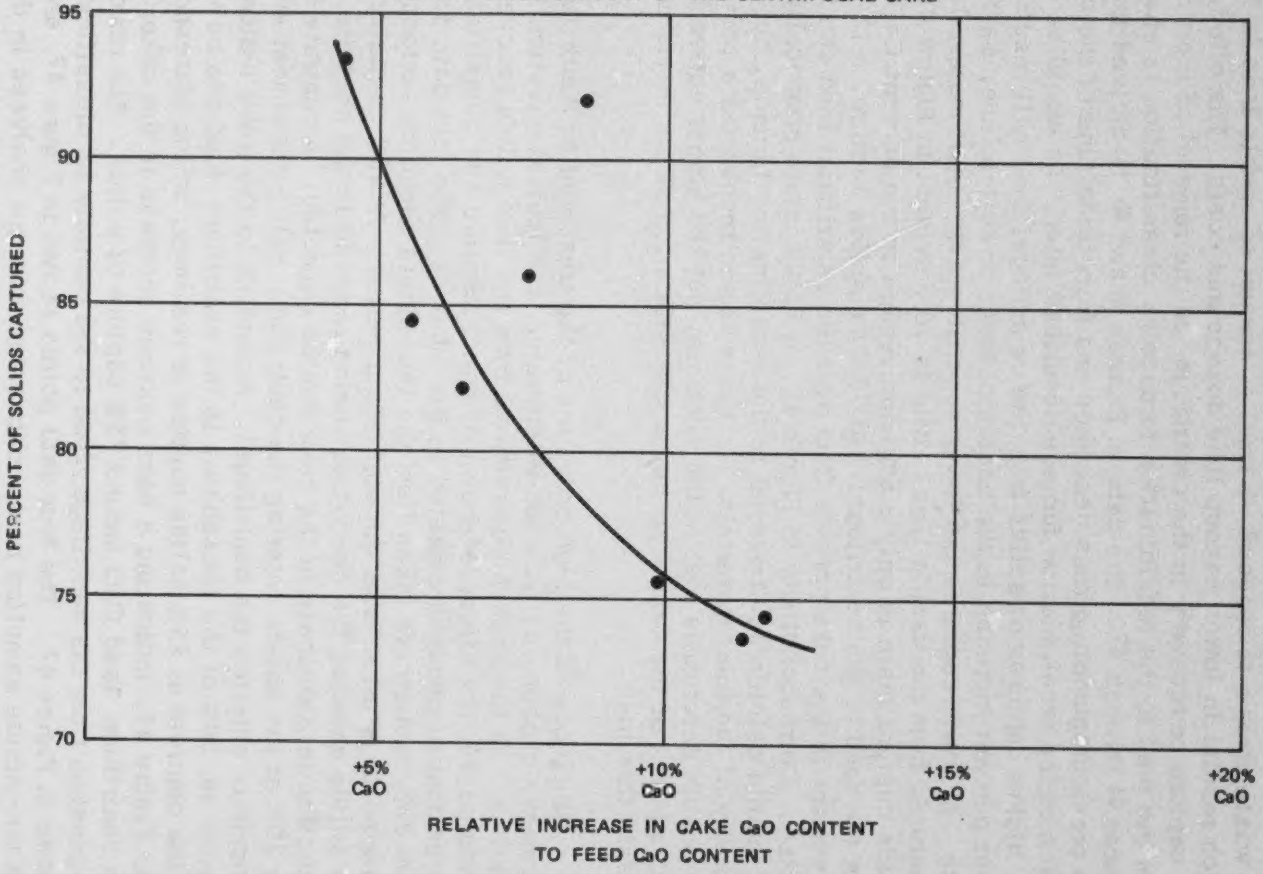


FIGURE 45
PERCENT SOLIDS CAPTURED
VS
PERCENT OF USABLE CALCIUM IN FEED CONVEYED TO FURNACE

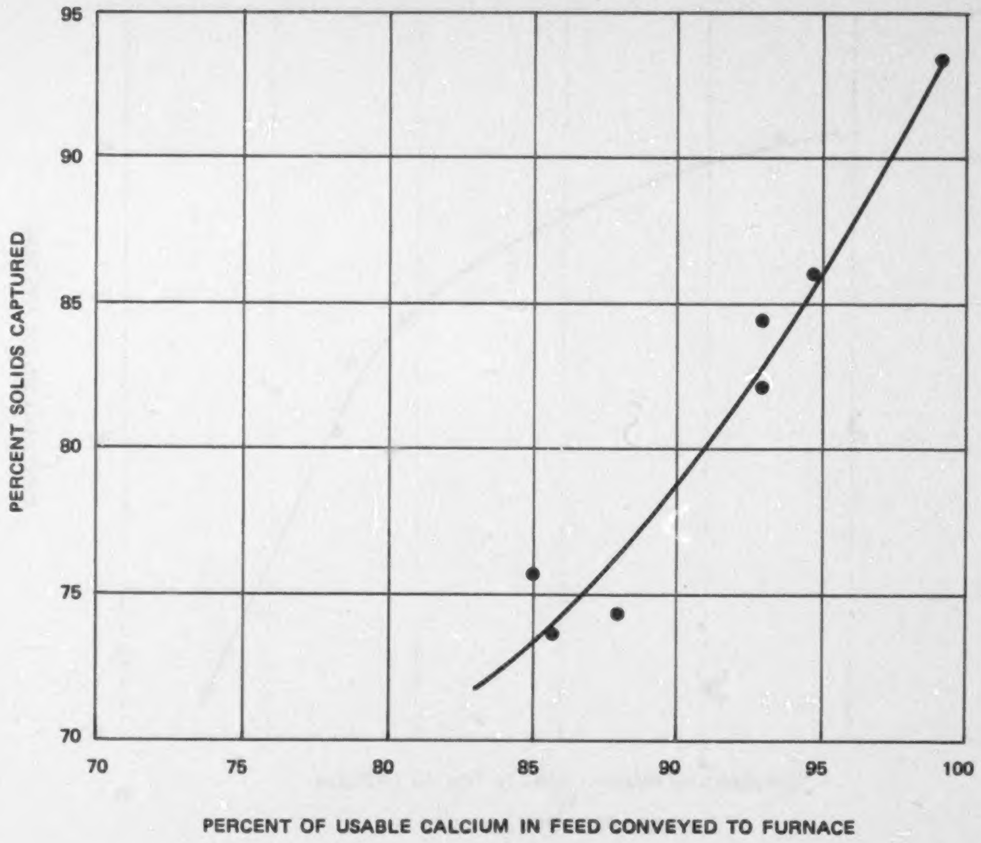


FIGURE 46
PERCENT SOLIDS CAPTURED
VS
PERCENT OF PO_4 IN FEED WASTED IN CENTRATE

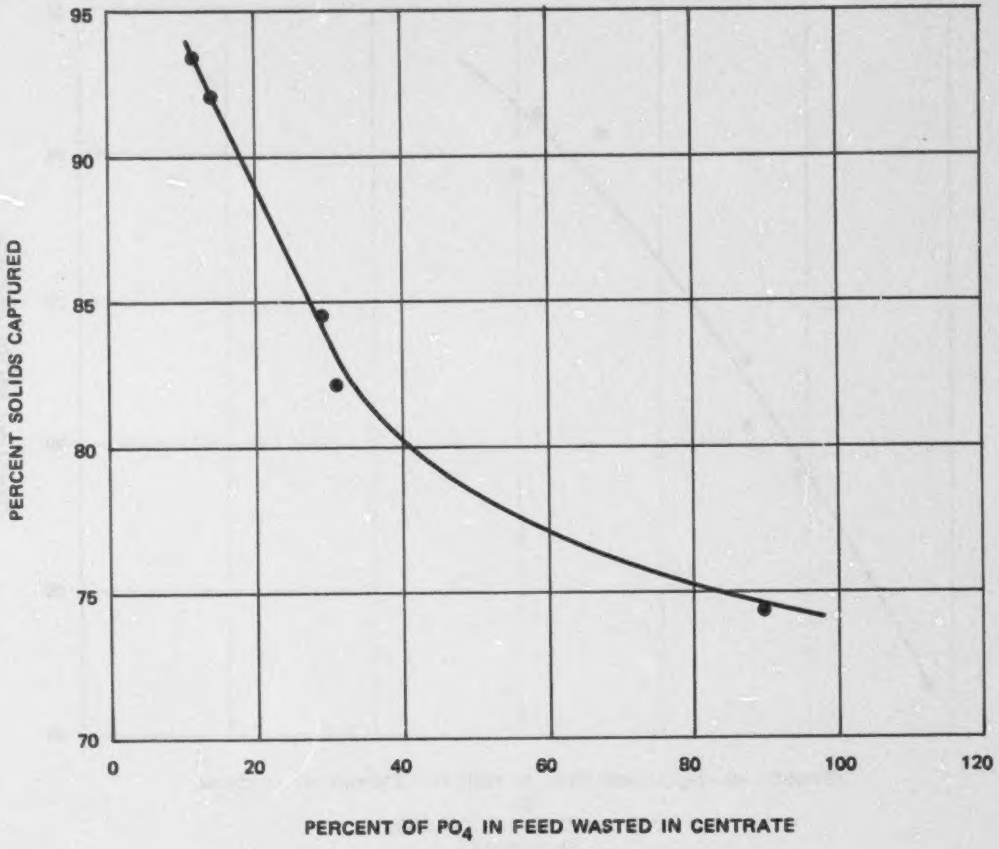
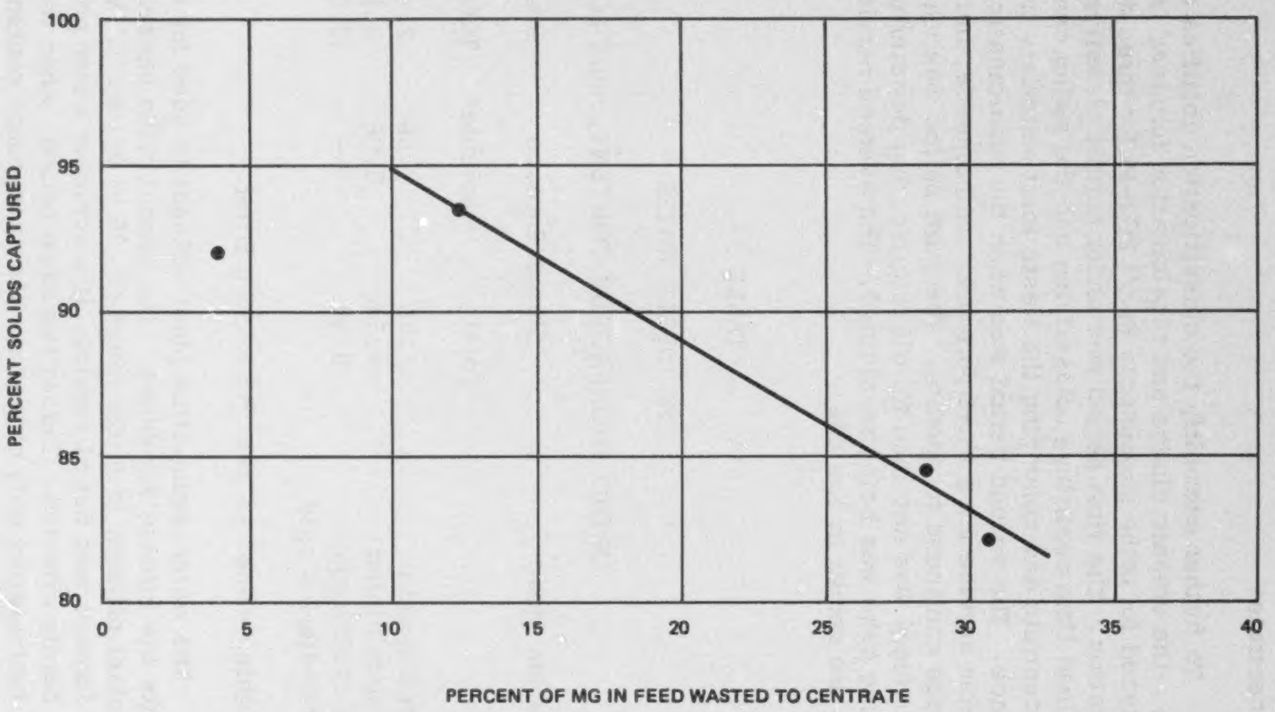


FIGURE 47

PERCENT SOLIDS CAPTURED
VS
PERCENT OF MAGNESIUM IN FEED WASTED TO CENTRATE



line, since the analysis for this run resulted in a 15% error in the magnesium balance around the centrifugal. However, the same trend as the wasting of phosphates in Figure 46 is indicated. At 80% capture, approximately 35% of the magnesium entering the centrifuge is classified into the centrate.

To further exemplify the classification abilities of the lime centrifuge the organic sludge and recalcination furnaces' scrubber waters were analyzed for ortho phosphorus (mg/l PO_4-P) for three different periods of operation. The first period was under normal classifying operations with the lead lime centrifuge classifying and the swing centrifuge dewatering the centrate and conveying the waste inert materials to the organic sludge furnace. The second period was when the recalcination furnace was removed from service for a short period for maintenance, but the organic solids furnace continued to operate. The third period was when the lead lime centrifugal was not used for classifying, but dewatering only, and the resulting cake was being recalcined. The average results of the three periods are shown in Table 14 .

TABLE 14

SCRUBBER WATER

ORTHO PHOSPHORUS CONTENT, mg/l PO_4-P

Operation Mode	Sludge Furnace		Recalcination Furnace	
	Total	Soluble*	Total	Soluble*
Classification	17.95	.56	2.4	.32
Not Recalcining	1.54	0.08	0.19	0.07
Lime Centrifuge for dewatering only	3.59	--	12.02	--

*Soluble defined as passing a .45 u filter.

The water reclamation plant effluent is used for the source of supply for the furnace scrubbers. The normal ortho phosphorus content of the plant effluent is in the range of .06 to 0.1 mg/l. When the recalcination furnace was out of service, it's scrubber water phosphorus content was barely affected. During the same period, when the sludge furnace was incinerating only organics, it's phosphorus content was 1.5 mg/l, all particulate. When the lead lime centrifuge is used for dewatering purposes only, the lime centrate is directed to the primary where the lime solids that are in the centrate settle out and are dewatered and dried or incinerated with the organic sludges. During this period the phosphorus content of the sludge furnace scrubber water increased to 3.5 mg/l, as a result of the lime centrate being directed to the primary. Since the lime centrifuge is operated with the highest possible solids capture when it is used as a dewatering device, the majority of the inert materials are conveyed to the recalcination furnace with the lime cake. This resulted in a much higher phosphorus scrubber water content of 12 mg/l. Only total ortho phosphorus was analyzed during this period. During the period of normal operations when the lead lime centrifuge is used for classification the sludge furnace, drying the concentrated waste lime inerts increased to 18 mg/l, mostly particulate. Since the majority of the inert materials had been classified out of the lime cake, the recalcination furnace scrubber water content decreased to 2.4 mg/l, mostly particulate.

Lime Mud Recalcining. Since April 1968 the District has successfully recalcined lime mud from the lime chemical treatment process. Over this period makeup lime has accounted for only 28 percent of the calcium oxide used. Average monthly CaO values in the recalcined lime have ranged between 51.0% and 74.7% with the average over the entire period being 66.0%. Table 15 shows the operating data for the lime mud recalciner. A reduction of approximately 40% in fuel requirements was achieved when centrifugal classification was used.

In an effort to measure the usable calcium losses in the recalcination furnace, the assumption was made that all the calcium lost as fly ash would be captured in the wet scrubber. The increase in calcium and phosphate in the scrubber water as a result of fly ash consisting of usable calcium and inert calcium hydroxyapatite was measured by acidifying the scrubber influent and effluent samples to pH 2.0, filtering with a .45 u filter, neutralizing the filtrate to pH 7 and analyzing for calcium hardness and phosphate. The phosphate was measured to determine the amount of calcium combined with the hydroxyapatite. The difference in terms of calcium, of the calcium hardness and the calcium combined with the hydroxyapatite provided the amount of usable calcium loss from the furnace. By measuring the amount of usable calcium in the centrifuge cake entering the furnace, described earlier in the classification and dewatering portion of this section, the percent calcium losses from the furnace can be determined. The amount of usable calcium loss from the furnace in the scrubber water was evaluated over an eight hour composite period. Using the analysis procedures and assumptions described above, 3.7% by weight of the usable calcium entering the furnace during the eight hour period was lost from the furnace.

TABLE 15

LIME RECALCINER OPERATING DATA

	No Centrifugal Classification	Centrifugal Classification
Period	Oct. 69 - May 71	July 70 - Nov.70
Chemical Clarifier Flow, MGD	2.95	3.63
Feed, lbs/hour(1)	435	756
Feed, % Solids	33.3	42
Electricity KWHR/day(2)	508	
Fuel Requirements,BTU/lb(3)	5500	3270

(1) Pounds of dry solids per hour

(2) Includes energy and demand charges for furnace support motors and recalcined lime conveying system. February 70 to December 1970

(3) Natural gas at 18 psia and 860 BTU/ft^3

Optimum Furnace Conditions. Eades and Sandberg in their discussion of lime reaction parameters point out that, "Although the art of lime burning has been practiced since ancient times, it was not until the 18th century that a scientific explanation of calcination was advanced. As industrial and chemical technology developed, lime became an increasingly important component in numerous reactions and processes. For these applications, the lime was judged primarily on its chemical purity, and minimal amounts of silica, alumina, iron, and other impurities were desired. In general, reaction rates were not thought important."

"Reaction rates of commercial limes became a matter of considerable interest with the introduction of the basic oxygen converter steel furnace. Operation costs for such converters are quite high, and steel producers quickly began investigation of methods to lower the time per heat of steel. Metallurgists became interested in the relationship between lime reactivity and slagging time. As a result of these and other studies, it quickly became apparent that in steel making and many other industrial applications reactivity of a lime was a more significant criterion for judging quality and suitability of a lime than chemical purity."

The authors further state, "that pore space and calcium oxide (CaO) crystallite size are the prime factors controlling reactivity of any given lime. These in turn can be linked to calcining conditions with low temperature burning producing a highly porous, highly reactive lime and high temperature burning producing a shrunken, dense lime with low porosity and low reactivity".

According to the AWWA Standard for Quicklime and Hydrated Lime (AWWA B202-65), high-reactive, soft-burned lime will show a temperature rise of 40°C in 3 minutes or less and the reaction will be complete within 10 minutes when tested by the method given in the standard. A medium-reactive, medium-burned lime will show a temperature rise of 40°C in 3 to 6 minutes and the reaction will be complete in 10-20 minutes. For low reactive, hard-burned lime more than 6 minutes will be required for a 40°C temperature rise and the complete reaction time will take longer than 20 minutes.

Since it is possible to produce quicklime with the same calcium oxide content, but with very different slaking properties, tests were performed on the lime recalcining furnace. The purposes of the tests were to determine the optimum recalcining temperature, feed rate and rabble rate in terms of lime reactivity and furnace fuel requirements.

The Rapid or EDTA Method for calcium oxide as described in Section XI and the AWWA Slaking Rate Test at 400 rpm were used to determine the reactive properties of the recalcined lime. At least an hour was allowed after changes in process variables to permit the furnace to reach equilibrium. A sample was then composited at 15-minute intervals from the No. 6 hearth for an additional hour. Composite feed samples were also collected at the same intervals and recalcined in the laboratory muffle furnace at 1800°F for 1 hour to insure that the potential input calcium oxide remained constant.

To establish a qualitative base line, calcium oxide and slaking rate tests were performed on virgin makeup lime. The data presented in Figure 48 shows that the makeup 16 x 50 mesh granular quicklime used at South Lake Tahoe is highly reactive. A 40°C temperature rise is reached in less than 30 seconds and the reaction completed in seven minutes. Identical results were achieved in three separate tests of the sample.

The effect of temperature on the recalcined lime activity at a constant feed and rabble rate was first investigated. Table 16 shows that recalcining temperatures between 1600°F and 1900°F had a major effect on recalcined lime activity, although all three temperatures produced lime which, under the AWWA standard, was considered to be highly-reactive. Within this temperature range there was no indication that the lime was being overburned, since the total reaction time was well within the time requirements. Recalcining lime at 1900°F as opposed to 1800°F produced a 5% increase in available calcium oxide, but very little improvement in an already acceptable slaking rate.

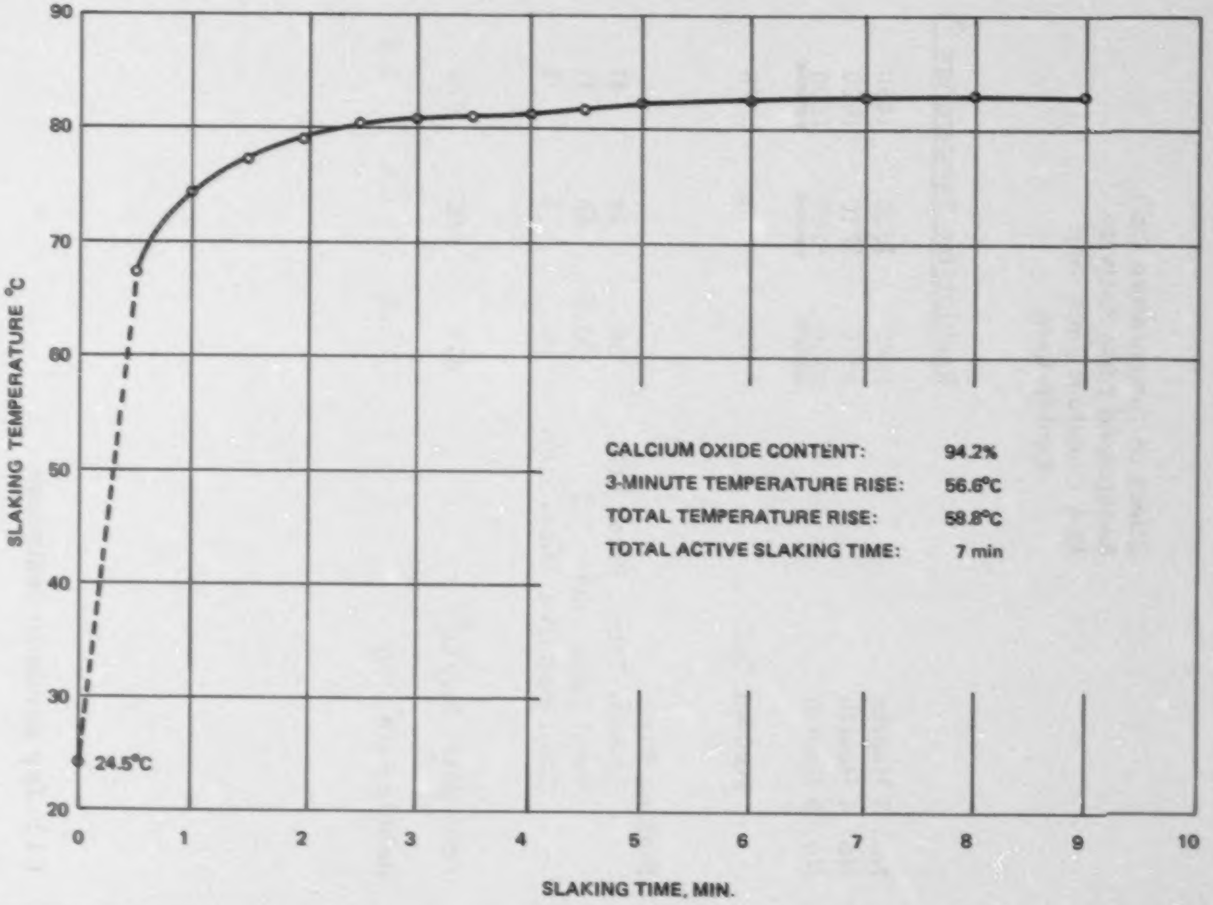
At 1600°F the flour-like recalcined lime showed pronounced tendencies to agglomerate into soft, easily crushed particles of 1/4 inch to 3/4 inch diameter. Many of the particles contained centers of unburned organic sludge. Additional evidence of unburned organic sludge was observed in the Dewar Flask after the slaking test.

For the second phase, the rabble rate was varied between 1.5 and 2.0 rpm while the temperature and feed rate were held constant. At both 1900°F and 1600°F the variation of rabble rate showed very little effect on the recalcined lime activity. Once again temperature proved to be the major variable. Table 17 shows the results of varying the rabble rate.

Finally, to determine the effect of feed rate, the temperature and rabble rate were held constant at 1900°F and 1.5 rpm, respectively. The feed rate to the centrifugal was run at 870, 820, and 450 pounds of dry solids per hour. Table 18 shows that the total slaking time doubled when the feed rate was reduced from 870 lbs/hr to 450 lbs/hr with no significant change

FIGURE 48

VIRGIN LIME SLAKING RATE TEST
AWWA STANDARD B202-65



CALCIUM OXIDE CONTENT: 94.2%
3-MINUTE TEMPERATURE RISE: 56.6°C
TOTAL TEMPERATURE RISE: 58.8°C
TOTAL ACTIVE SLAKING TIME: 7 min

TABLE 16

Effect of Temperature On Recalcined Lime Activity At a Constant Feed and Rabble Rate

	Recalcining Temperature °F		
No. 3 Hearth	1640	1630	1450
No. 4 Hearth	1900	1710	1620
No. 5 Hearth	1900	1780	1600
Percent CaO	86	81	76
Slaking Rate:			
60 Sec. Temp. Rise, °C	50	48	41
Total Temp. Rise, °C	51.5	48	41
Total Reactive Time, min.	2	1	1
Feed Rate, lbs/hr(1)	870	800	870
Rabble Rate, rpm	1.5	1.5	1.5

---

(1) Dry solids to centrifuge

TABLE 17

Effect of Rabble Rate
On Recalcined Lime
Activity At a Constant
Feed Rate

	Rabble Rate, rpm	
	2.0 rpm	1.5 rpm
1900°F Avg Temp (1)		
Percent CaO	86	86
Slaking Rate		
60 Sec. Temp. Rise, °C	51.5	50
Total Temp Rise, °C	52	51.5
Total Reaction Time, min.	1.5	2
Feed Rate (2), lbs/hr	940	870
1600°F Avg Temp (1)		
Percent CaO	70	76
Slaking Rate		
60 Sec. Temp. Rise, °C	39	41
Total Temp Rise, °C	39.5	41
Total Reaction Time, min.	2	1
Feed Rate (2), lbs/hr	830	870

(1) Average of No. 4 & No. 5 Hearth temperatures
(2) Dry solids to centrifuge

TABLE 18

EFFECT OF FEED RATE ON RECALCINED LIME ACTIVITY AT 1900°F (1) AND 1.5 RPM RABBLE RATE

	FEED RATE (2) lbs/hr		
	870	820	450
Percent CaO	86	90	89
Slaking Rate			
60 Second Temp. Rise, °C	50	50.5	50.5
Total Temp. Rise, °C	51.5	53.5	53.5
Total Reaction Time, min.	2	2.5	4

(1) Average of No. 4 and No. 5 hearth temperatures

(2) Dry solids to centrifuge

in the calcium oxide content. All three feed rates produced highly-reactive recalcined lime under the AWWA standard. However, the lower feed rate produced a less reactive lime.

The optimum furnace conditions in terms of recalcined lime activity appear to be about 1900°F on the fourth and fifth hearths at 1.5 to 2.0 rpm rabble rate for 800-900 lbs/hr of dry solids to the centrifuge. The centrifuge was being used as a classifying device during this test period. On the basis of the 75% capture that was obtained, the actual furnace feed rate for the optimum conditions was 600 to 700 lbs/hr.

A slightly less reactive lime was obtained at an average recalcining temperature of 1750°F. At the same loading rates and taking into consideration the higher natural gas consumption, increasing the calcium oxide content from 81% at 1750°F to 86% at 1900°F saved approximately $2.00 per ton of dry solids fed to the furnace.

The soft burned recalcined lime produced at South Lake Tahoe has, as previously mentioned, a flour-like texture. Individual particles are not easily seen without magnification. The large surface area to volume ratio makes the recalcined lime very easy to slake. Tables 16, 17 and 18 all indicate that the total slaking time was four minutes or less; whereas the highly reactive 16 x 50 mesh granular makeup lime required seven minutes for total slaking.

Conclusions. At the 7.5 mgd design flow about 34 tons per day of dewatered lime would have to be disposed of if lime recovery and reuse were not practiced. Through lime recalcination the total blow-down of waste solids is reduced to approximately 1.5 tons of dry solids. The cost of recalcined lime is slightly more than that of new lime, however, the reuse has and will avoid the costs of disposal and purchase or production of CO_2. Lime recovery and reused at South Lake Tahoe has demonstrated the following:

1. Lime recalcination provided not only 72 percent of the lime used for the past three years, but also a usable source of carbon dioxide.

2. Industrial gravity type thickeners are an effective device for thickening lime mud containing organic solids with very low weir overflow losses of usable calcium.

3. A concurrent flow centrifuge can be used to separate or classify phosphate rich inerts and magnesium from reusable calcium carbonate.

4. Three centrifuge bowl speeds, 2200, 1800, and 1600 rpm, were used to determine optimum bowl speed. All three speeds produced approximately the same percent cake solids and recovery or capture. Consequently the lowest bowl speed, 1600 rpm, was selected for plant operations to reduce wear and maintenance costs.

5. The lime centrifuge performed as expected with high solids captures at high pool depths and lower flows to the machine. Conversely, at low pool depths and higher flows solids capture was less.

6. At 9 tons of solids to the furnace per day, the optimum recalcining conditions were 1900°F on the number 4 and 5 hearths with a 1.5-2.0 rpm rabble rate.

7. Of the three parameters, recalcining temperature, rabble rate and feed rate, temperature had the most effect on recalcined lime activity. The CaO content in the recalcined lime was increased 15% by raising the temperatures from 1600°F to 1900°F.

SECTION XVIII

NITROGEN REMOVAL

General. Nitrogen removal appears to be the major remaining barrier to disposal of reclaimed water in the Tahoe Basin. Since there is some opinion that algal growths in Lake Tahoe are presently nitrogen limited, it is quite possible that nitrogen removal must be successfully demonstrated on a plant scale prior to any possible reconsideration of in-basin reuse or disposal of purified wastewater. Also, in many water short areas of the world, the need for an economical and reliable means of removing nitrogen from wastewater has prompted many pilot studies of the various methods of removing nitrogen from wastewater. Basically these were the reasons for extensive ammonia stripping pilot studies carried out by Smith and Chapman at South Lake Tahoe. Upon completion of the pilot plant tests with a 24-foot countercurrent tower, it was decided to build a plant scale unit to one-half total plant capacity to verify pilot plant results and to evaluate such potential problems as freezing and calcium carbonate scaling. Although after six months of testing, scaling on the pilot tower fill was not evident, it was felt this problem might arise in a full scale tower, and the possibility of altering the original design would be less difficult for a tower built to one-half plant capacity. In the same light, tower freezing problems in the winter and their possible solutions or alterations could be accomplished more easily on a smaller tower.

Ammonia Stripping Tower Physical Description. The principal design features of the Tahoe ammonia stripping tower are given in Table 19. Although the pilot towers were countercurrent airflow towers, the full-scale tower was designed as a cross flow unit.

The completed tower is shown in the photograph of Figure 49. The overall dimensions of the tower are 32 feet x 64 feet x 47 feet high. Water, at pH = 11, is pumped to the top of the tower by one of two constant speed pumps. These pumps are backflushed two or three times daily to minimize buildup of calcium carbonate scale in the pump units. When the

TABLE 19

DESIGN DATA FULL SCALE AMMONIA STRIPPING TOWER

Capacity: Nominal, 3.75 mgd

Type: Cross flow with central air plenum and vertical air discharge through fan cylinder at top of tower

Fill:

Plan area, 900 square feet
Height, 24 feet
Splash bars:
  material, rough sawn treated hemlock
  size, 3/8" x 1-1/2"
  spacing, vertical 1.33 inches
    horizontal 2 inches

Air Flow:

Fan, two-speed, reversible, 24-foot diameter, horizontal

Water Rate		Air Rate	
gpm	gpm/sf	cfm	cfm/gpm
1,350	1.0	750,000	550
1,800	2.0	700,000	390
2,700	3.0	625,000	230

Tower Structure: Redwood

Tower Enclosure: Corrugated cement asbestos

Air Pressure Drop: 1/2 inch of water at 1 gpm/sf

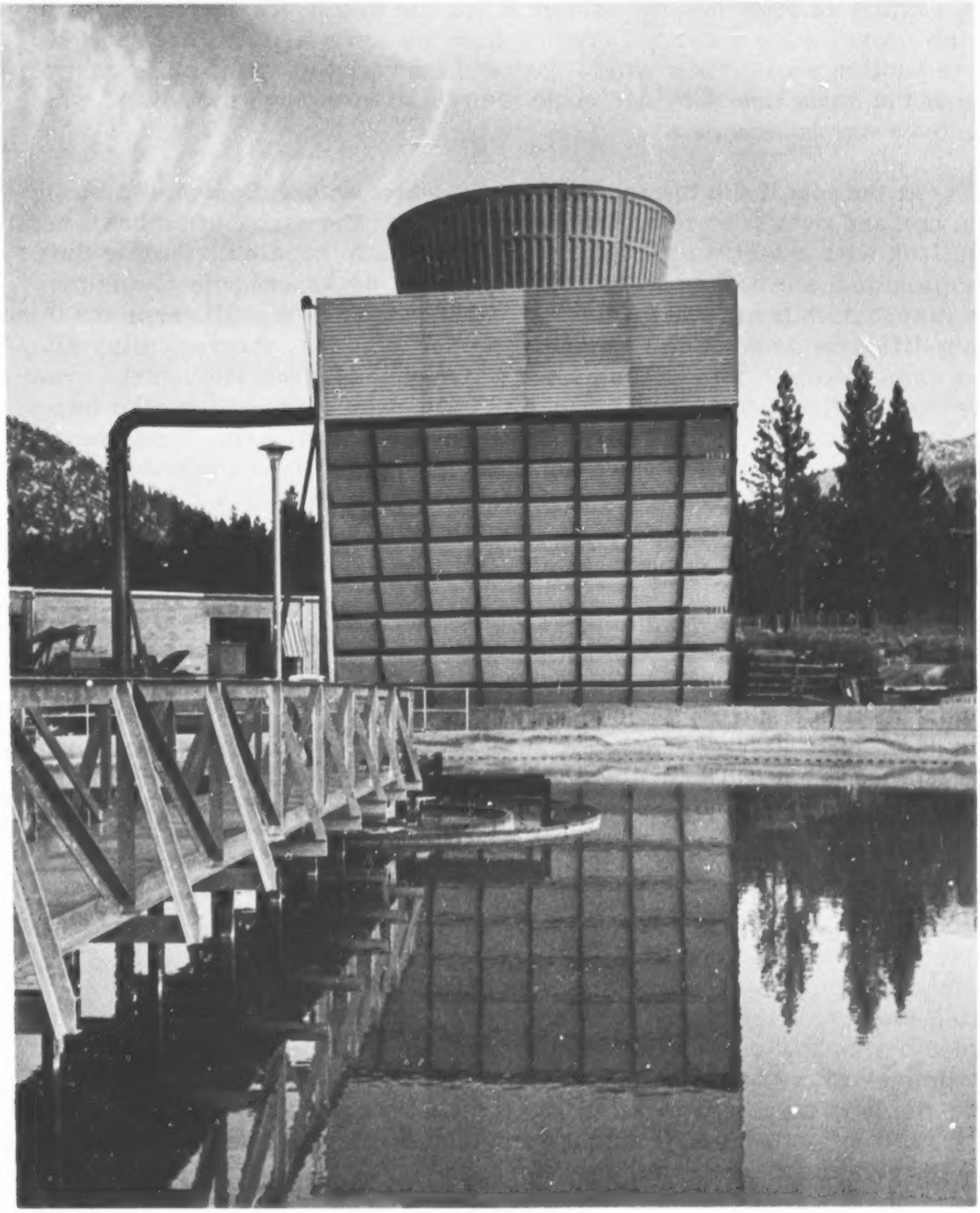


Figure 49

NITROGEN REMOVAL TOWER

NOT REPRODUCIBLE

plant inflow is less than the rate at which the pumps are delivering water to the tower, some water is recycled from the tower effluent back to the pump suction well. This avoids the need for variable speed pump control, and at the same time provides some recirculation through the tower, which improves ammonia removal.

At the top of the tower, the influent water enters a covered distribution box and overflows to a distribution basin. The distribution basin is a flat deck with a series of holes fitted with plastic nozzles. Further distribution of the inflow is provided by diffusion decks immediately below the distribution basin. At 6-foot vertical intervals in the fill there are three other diffusion decks. The tower fill proper provides, theoretically, 215 successive droplet formations as the water passes down through the tower. The tower effluent falls into a concrete collection basin which also forms the base for the tower structure. From the collection basin, the tower effluent passes through a rectangular measuring flume into a chamber, where, as previously mentioned, excess pumpage returns through a flap gate into the tower pump sump to be recirculated through the tower. The remaining flow passes from this chamber to the first stage recarbonation section.

Air enters the tower through side louvers, passes horizontally through the tower fill and enters a central plenum. At the top center of the plenum is a 24-foot diameter, six-bladed, horizontal fan. Fan blades and fan cylinder are both made of glass-reinforced polyester. The fan takes suction from the plenum and discharges to the atmosphere through the fan cylinder. The fan has a maximum capacity of about 750,000 cfm. It is equipped with a two-speed, reversible 100 hp motor. The tower was constructed in the summer and fall of 1968, and put on line October 29, 1968.

Tower Performance. Initially, tower operation was on an intermittent basis as a result of extreme cold and snow conditions in November, 1968. In the later part of November through January some operational results were obtained when weather conditions permitted. In Table 20 are listed the operating parameters and the ammonia removal efficiencies obtained during low temperature winter operation. The air/water ratio is computed with a theoretical fan output curve provided by the manufacturer. From the data tabulated in Table 20, the air temperature ranged from 31 to 43°F, the influent water temperature ranged from 48 to 52°F, and the average temperature drop through the tower was 14°F. The surface loading rate averaged 1.9 gpm/sf, with a range of 1.2 to 2.9 gpm/sf. The theoretical air to water ratio, cf/gal, averaged 535, with a range of 235 to 750 cf/gal. The pH of the tower influent water averaged 10.7 with an average drop of 0.1 pH unit through the tower. The average percent removal of ammonia was 64%, with a range of 47 to 89%. From the pilot plant data, Smith and Chapman, indicated that the probable average lower limit of ammonia

TABLE 20

LOW TEMPERATURE AMMONIA STRIPPING AT SOUTH LAKE TAHOE PLANT

Date	Air Temp °F	Water Temp °F		Flow Rate mgd(1)	Load- ing gpm/ft^2	Theo. Air/ Water cf/gal	pH		Ammonia Removal		
		In	Out				In	Out	In	Out	% Removal
11-27-68	41	52	37	3.8	2.9	235	11.	11.2	16.2	6.9	58
11-28-68	38	52	39	3.3	2.5	290	10.6	10.5	13.9	6.8	51
11-28-68	39	54	36	1.7	1.3	650	10.8	10.8	14.3	2.6	83
11-29-68	40	54	37	1.7	1.3	650	10.5	10.5	16.1	7.1	56
11-29-68	41	54	37	1.7	1.3	650	10.5	10.5	16.4	7.8	52
12-23-68	34	48	41	3.0	2.3	355	10.6	10.5	17.1	8.1	47
1- 3-69	43	54	45	3.8	2.9	235	10.7	10.5	18.2	8.7	52
1- 3-69	41	54	41	2.6	2.0	390	10.6	10.4	19.6	6.9	65
1- 3-69	31	52	34	2.6	2.0	390	10.0	10.0	18.6	7.8	58
1- 3-69	43	54	43	2.2	1.7	475	10.7	10.5	20.8	4.7	77
1- 4-69	42	52	39	1.9	1.5	570	10.6	10.6	16.4	3.6	78
1- 4-69	40	52	37	1.9	1.5	570	10.9	10.7	16.2	5.7	65(2)
1- 6-69	39	50	36	1.5	1.2	750	10.7	10.3	13.3	1.4	89

(1) No Recirculation
(2) Ice Formation

removals during winter conditions would be in the range of 50 to 60%. Consequently, the full scale tower data does compare quite well with the pilot plant results. Also there was no recirculation for the data in Table 20, that is the data represents one pass through the stripping tower. In Figure 50 the data from the full scale tower is superimposed on the pilot data from Smith and Chapman. The pilot data in Figure 50 is taken from optimum summer temperature conditions, and the full scale data is for the conditions shown. Figure 50 indicates the reduction in effective packing depth as a result of the lower temperature. Although the wastewater passed through the 24 feet of packing in the full scale tower, the ammonia removal efficiency was comparable to passing through only about 15 feet of packing. This also indicates approximately the recirculation required at low temperatures to achieve a desired ammonia removal. Further, Figure 50 indicates to what extent the air to water ratio must be increased during low temperatures to achieve a desired ammonia removal efficiency. For example, to achieve 90% ammonia removal for an air temperature of 40°F, a water temperature of about 50°F, proper pH conditions, and an air to water ratio of 750 to 800 cf/gal of water would be required.

In Figure 51, the full scale low temperature data is superimposed on pilot data. At low temperature the full scale removals fall off sharply with increased surface loading rate, and again compared with the removal efficiency of approximately 15 feet of packing, rather than the 24 feet of packing which the wastewater actually passed through. The low rate of loading to achieve a significant removal is also shown in Figure 51.

In Figure 52, full scale data is again superimposed on the Smith and Chapman data for different tower depths. The full scale data compared very well with the pilot data for ammonia removals at approximately the same operating conditions of surface loading rate, air to water ratio, and influent and effluent water temperatures. Only single points are shown on Figure 52, since the full scale tower can only be operated at packing depth of 24 feet.

Unfortunately, after about three months of operation, the tower fill started to become encrusted with calcium carbonate scale. Although the scale could be easily removed from the splash bars with a water jet, the structural members holding the fill in place prevent the scale from being completely removed from the tower. The blocked portions of the fill resulted in short circuiting the water and airflow, and hence lower ammonia removals. As a result of the scale, ammonia stripping under optimum

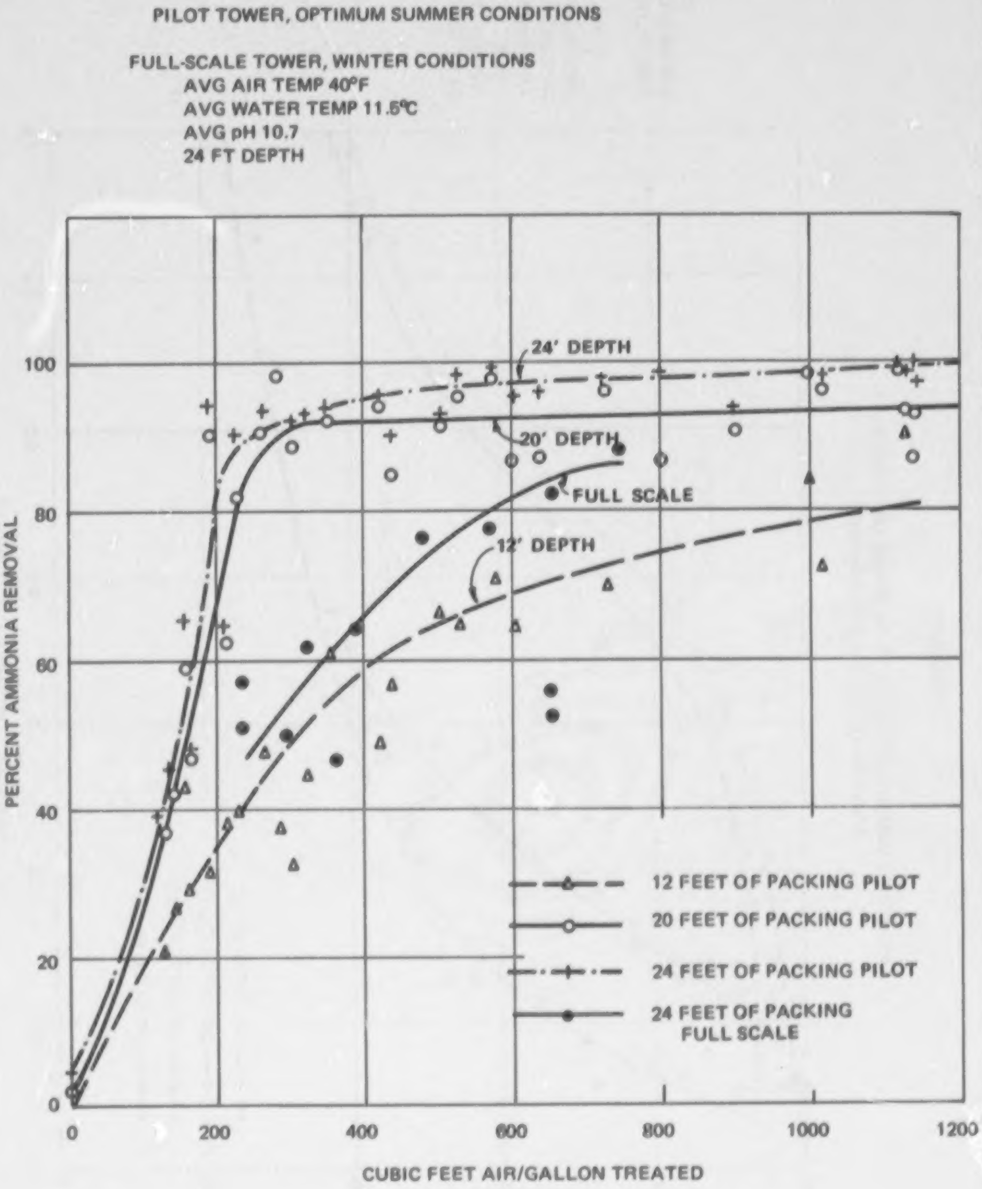
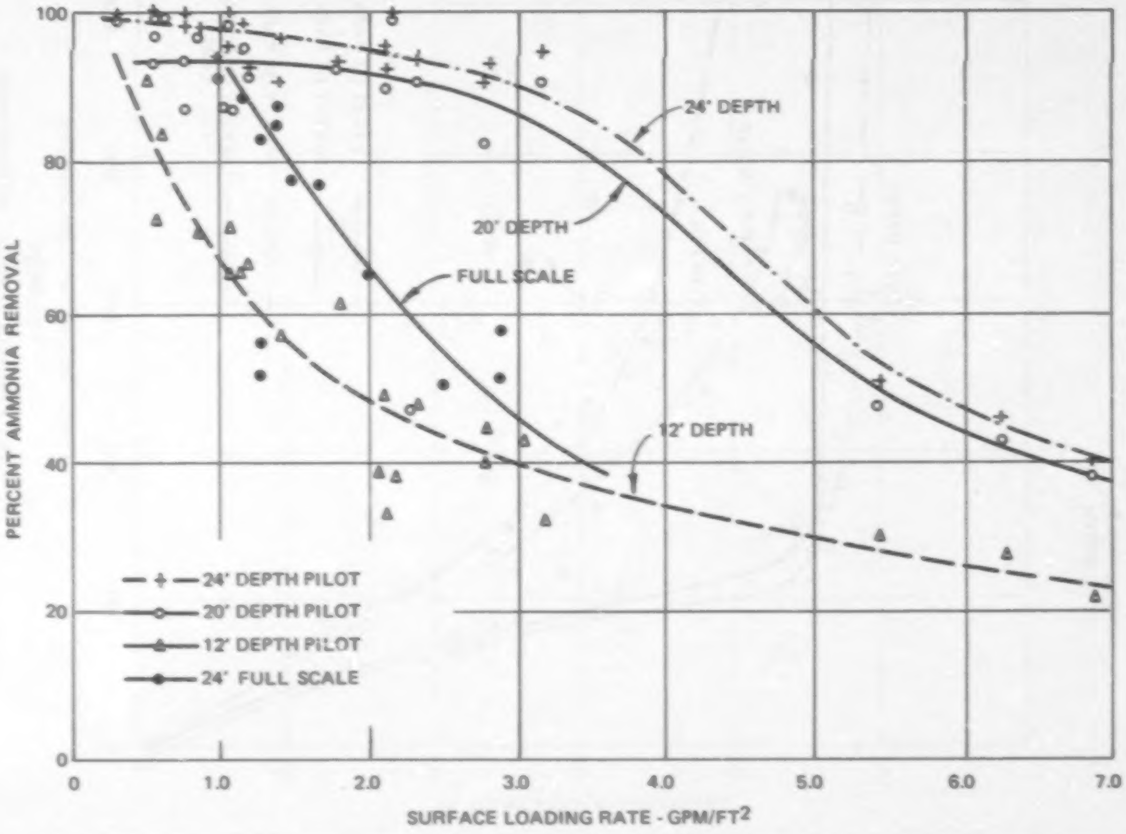


FIGURE 50

PERCENT AMMONIA REMOVAL VS. CUBIC FEET
OF AIR PER GALLON WASTEWATER TREATED
FOR VARIOUS DEPTHS OF PACKING

FIGURE 51

PERCENT AMMONIA REMOVAL VS. SURFACE LOADING RATE
FOR VARIOUS DEPTHS OF PACKING



OPTIMUM
SUMMER CONDITIONS
FOR PILOT TOWER

FULL-SCALE
WINTER CONDITIONS
AVG AIR TEMP - 40°
AVG WATER TEMP - 11.5°
AVG pH - 10.7
24 FT DEPTH

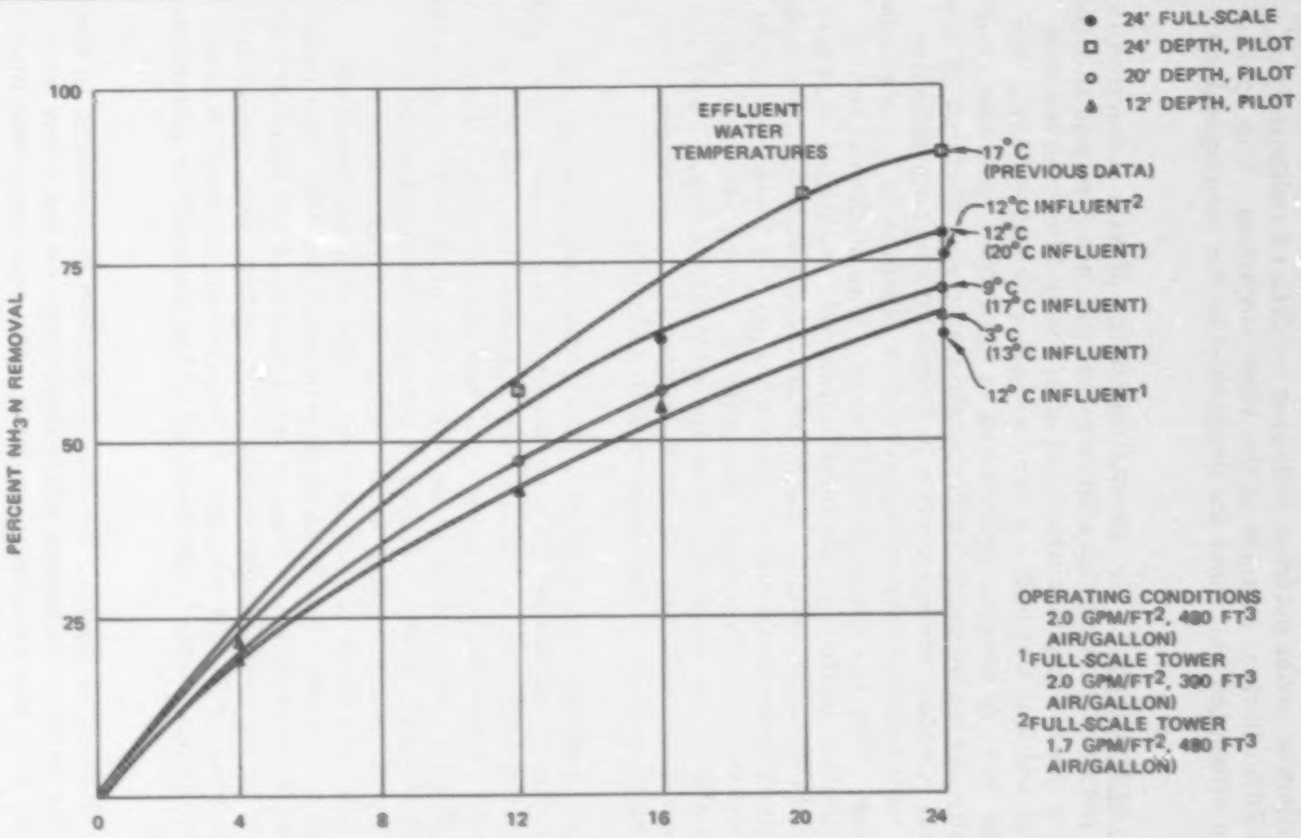


FIGURE 52

EFFECT OF WATER TEMPERATURE ON AMMONIA STRIPPING warm weather conditions could not be evaluated properly. However, intermittent data collected under optimum stripping conditions indicated the tower could be 70% efficient in spite of the short circuiting. The scale buildup and the attempted solutions are discussed in the subsequent section.

Operational Problems. The intermittent dates of data collection in Table 20 are a result of shortage of analysis time and are also due to freezing conditions in the tower under which the tower would be removed from service until the ambient wet bulb air temperature went above 32°F. The freezing problem was, of course, recognized in pilot plant operation, but could not be fully evaluated until the full scale tower was operated at low air temperatures. Cooling towers similar in design to ammonia stripping towers operate very successfully in severe winter climates in the northern U.S. and Canada. This is done in several ways. One method is to use large flow distribution orifices at the outside face of the tower. This concentrates a curtain of warm water at the point where the cold air first enters the tower and gives some protection against freezing. If there is a slight ice buildup on the outside tower face, the draft fan can be reversed, thus blowing warm inside air to the frozen area and melting the ice. These are satisfactory ways to prevent freezing, or to correct it, in a cooling tower because the desired cooling of the water is still obtained.

These same methods were tried at Tahoe. The tower was able to operate at temperatures as low as 25°F by reversing the fan at a slow speed for 25 minutes every 1-1/2 hours. This method of operation created an additional work load on the plant personnel and was discontinued. Larger orifices were placed on the outside 18 inches of the tower distribution basin to provide the sheeting effect. Although the modification seemed to help, the freezing condition existed until the arrival of above freezing temperatures. Also, at these low temperatures, the ammonia removals drop to less than 30 percent, which is of questionable benefit. The operation of the plant-scale tower has demonstrated that it is not practical to operate the tower at air temperatures below 32°F; unless large waste heat sources are available, it is not practical to heat the air or water in order to prevent ice formation on the tower because of the tremendous quantities of heat required.

As briefly discussed earlier, the second problem encountered in tower operation is the calcium carbonate scale deposition on the tower pump, distribution deck, fill, and structural members. The countercurrent pilot tower was checked very carefully periodically over a period of six months of operation with lime adjustment at pH=10.8, and there was no evidence of scale buildup. However, several months after the full scale tower pumps were started, a sharp decrease in pump efficiency was encountered due to a buildup of scale on the impellers. Baffles were then installed in the first stage recarbonation basin below the tower to prevent migration of CO_2 to the pump sump. Although these baffles seemed to help, the problem was not completely alleviated until the pumps were allowed to run without being throttled and a regular schedule of pump backflushing was initiated. The schedule of backflushing apparently solved the scale problem and the pumps can be operated at lower flows without losing too much efficiency. The deposition of calcium carbonate within the fill area of the tower has been the most serious problem. The amount of material deposited on the splash bars has been sufficient to restrict the flow of both air and water. The distribution of water has been very uneven throughout the tower with some areas receiving little or no water while sheeting occurs in other areas. Since the scale which forms is soft and friable, it can be removed quite readily with a high pressure spray. However, the tower structural members which hold the splash bars in place prevent the scale from being completely removed from the tower. In addition, three horizontal layers within the fill, each approximately four inches thick, cannot be reached for cleaning because of the tower's structural design. Droplets pool above these layers, flowing to outer edges of the fill and then sheet down the sides of the tower. The problem of how to clean these layers without repacking the entire tower has not been solved.

Plastic fill was installed near the top of the tower to evaluate the calcium carbonate incrustation on this type of material. It appeared the buildup was similar in quantity to the amount deposited on the hemlock fill, but the buildup was easier to remove from the plastic material with water spray.

An attempt was made in January, 1970 to chemically clean the tower fill of the calcium carbonate incrustation. After consultation with chemical company personnel, it was decided to use a combination of pH shock with sulfuric acid and a cooling system dispersant. The sulfuric acid was used to increase the stability index of the batch solution to a corrosive tendency, allowing the dispersant to penetrate through the incrustation and physically remove it with the hydraulic flow. The stability index of the water flowing through the tower during normal operation is around 3-4, having a high scaling tendency. The stability index of the batch solutions used for cleaning was between 7 and 8, having a moderately corrosive tendency. An acid dosage of 210 mg/l was used in the batch cleaning solution. A dosage of 300 mg/l was used for the dispersant.

The following procedure was used in the attempted chemical cleaning of the fill. First, the accessible portions of the fill and the tower catch basin were cleaned with the water spray. Second, the ports between the tower sump and the first stage recarbonation basin were blocked to enable the entire batch cleaning solution to be recirculated over the tower. Third, the tower sump was filled with No. 3 or plant effluent water, and the acid and dispersant added to the sump. Initially the batch solution was dark brown in color, and after recirculation through the tower from 3-6 hrs. it became light yellow. The stability index changed from 7.9 to 7.2. The pH of the solution before and after was 7.2. Six batch solutions were recycled over each side of the tower for about 6 hours each. The spent batch solutions were pumped to a drying bed to prevent possible detrimental effects to plant treatment processes. The cleaning solution was then introduced at very low flows back into the ballast ponds with no measurable effect on the processes or final effluent quality.

Ammonia removal efficiencies after the chemical cleaning indicate the tower is still about two-thirds as efficient as the tower was before the initial calcium carbonate incrustation in February, 1969. Approximately 870 cubic feet of lime sludge was removed by the chemical treatment. However, since some water sheeting is noticeable on the outside tower face and since ammonia removals did not improve appreciably, it is suspected that inaccessible areas trapped the chemically treated sludge, thereby still interferring with proper droplet formation and air flow. An interesting side light to the tower cleaning was the tower pump's discharge pressure doubled, reaching its original 18 psig pressure, indicating the pump had been thoroughly cleaned. Also several pieces of the scale approximately 1/2" thick, and rounded to conform to the pressure pipe leading to the top of the tower, were found on the tower's warm water deck. This would indicate this line had also been cleaned. It would appear the chemicals used were successful in removing the scale, but the chemically treated sludge could not be completely removed from the tower fill. The cost of chemicals for one cleaning of the tower was less than $200.00.

In ammonia stripping of waters which form this soft scale as at Tahoe, it is a simple matter to provide for easy, inexpensive removal of the deposits by providing complete accessibility to the fill, so that once the scale is removed from the splash bars, it can be hydraulically carried out of the fill area. The provision for complete accessibility of the fill area might be facilitated by the following four possible alternatives of cleaning the stripping tower of calcium carbonate scale. First, a system of water sprays or nozzles incorporated into the tower design used specifically for cleaning purposes, and operated at regular intervals. Second, in place cleaning of a completely accessible tower fill with a high pressure spray to remove the scale from the splash bars and carry it out of the fill area. With this method, the maximum width of the fill should be around 10 feet with access from both sides. Third, the fill could be designed in modules, so it could be removed from the tower, cleaned and replaced with little difficulty. Fourth, chemical cleaning of the fill could be accomplished economically and with very little physical work, however, once again, the tower design would have to permit complete removal of the sludge from the fill. Soft scale formation in the tower can be overcome and therefore should not be a reason for eliminating ammonia stripping. In the treatment of some waters hard scale may be formed which cannot be removed. Stripping may not be feasible in locations where hard scale is formed.

Tower Off Gases. Under most conditions the off gases from an ammonia stripping tower will present no problems. Because of the high air to water ratios required for efficient tower operation, the ammonia concentration in the off gases will be less than 6 mg/cubic meter, while the threshold for odor is about 35 mg/cubic meter. Under unusual conditions where the atmosphere is already polluted with high concentrations of sulfur dioxide, ammonia may react with the sulfur dioxide to form an aerosol or fog.

Ammonia may be washed out from air by rainfall, but not by snowfall. The natural background concentration of ammonia in the atmosphere is 5 ugm/m^3, and in rainfall the natural background ranges from 0.2 mg/l to 1.0 mg/l.

Calculations for the ammonia washout in a rainfall rate of 3 mm/hr have been made for a stripping tower with a capacity to treat a flow of 15 mgd (ultimate design capacity at South Tahoe), or a source emission rate of 4.7×10^4 gm/hr. The peak ammonia concentrations of ammonia in the rainfall would be 2.0 mg/l at a distance of 2,000 meters from the tower and would be only 0.5 mg/l at a distance of 5,000 meters (which is approaching natural background). The ultimate fate of the ammonia which is washed out by rainfall depends upon the nature of the surface upon which it falls. Most soils will retain the ammonia. That portion which lands on paved areas will appear in the runoff from that area.

For the same conditions except no rainfall and assuming no dry deposition, the surface air concentrations of ammonia would vary from 0.041 mg/m^3 at 2,000 meters to 0.0065 mg/m^3 at 5,000 meters. Thus it is apparent that the surface air concentrations of ammonia are far below the threshold odor level, and further, that no significant changes in the atmospheric environment result from ammonia stripping.

Summary and Conclusions. Under the right climatic conditions and with the proper precautions regarding scale prevention or removal, ammonia stripping is a practical, reliable method for nitrogen reduction. One of the greatest advantages of this method of nitrogen removal is its extreme simplicity and low operating cost. Water is merely pumped to the top of the tower at pH=11, air is drawn through the fill, and the ammonia is stripped from the water droplets. The only control required is to maintain the proper pH in the influent water. This simplicity of operation also very much enhances the reliability of the process. Full scale testing showed the following:

1. Performance of the full-scale tower closely parallels that of the pilot tower insofar as ammonia removals are concerned. At similar hydraulic loadings, air flows, and water and air temperatures, the results with the full-scale cross-flow tower are much the same as with the pilot countercurrent tower.

2. During low temperature winter operations, before the presence of calcium carbonate scale on the fill, the tower achieved an average of 64% removal efficiency with a range of 47% to 89%.

3. It is necessary to either recirculate wastewater or to reduce the surface loading rate to about 1.0 gpm/sf and raise the air to water ratio to 750-800 cf/gal to achieve 90% ammonia removals at low air temperatures above 32°F.

4. Sheeting water down the side of the tower fill and reversal of the induced air fan enable tower operation slightly below 32°F, but generally it is not economical or practical to operate the ammonia stripping tower below 32°F wet bulb air temperature. In cold climates, if ammonia stripping is used, and if nitrogen removal is required during freezing weather, then ammonia stripping may be used at temperatures above 32°F and a supplemental method used at colder temperatures.

5. Calcium carbonate scale can be expected on the tower fill area of a crossflow ammonia stripping tower. As a result of this fact, the tower fill should be designed for complete accessiblity to provide for physical or chemical cleaning and removal of the scale from the tower.

6. It was not possible to properly evaluate ammonia stripping efficiency at optimum summer conditions in the present tower because of calcium carbonate scale buildup.

SECTION XIX

MIXED MEDIA FILTRATION

General. The production of high quality reclaimed water from wastewater requires the use of efficient filtration. The key to the successful operation of the entire Tahoe plant is the good performance of the mixed-media filters. The importance of filtration to the overall treatment scheme was recognized by the consulting engineers from the very beginnings of the project in 1961. For fifty or one hundred years, engineers had attempted without success to clarify sewage using fine screens, san, diatomaceous earth, and other types of mechanical strainers or surface type filters. These efforts, and similar ones at Tahoe, failed because of the tremendous volume of solids to be removed and stored and the fragile and sticky nature of these solids. On any surface filter, solids accumulate rapidly and blind the surface. This causes high head loss followed by the breakthrough of particulates as operating pressures are increased. The practical engineering solution of these problems came about by the development of in-depth, coarse-to-fine filtration combined with the use of alum or polymers as filter aids. The first successful sewage filter of this type was the dual-media filter. It extended the effective depth of filtration from the 2 to 6 inches available in a sand filter to 12 inches or more. Further refinement and development produced the mixed media filter which has pore space which is uniformly tapered from coarse-to-fine throughout the full depth of the bed, so that solids are removed and stored throughout the full 36 inches or more of bed depth. The use of a filter aid such as alum or a polymer results in coagulation, flocculation, and adsorption of not only more particulate matter in the filter but also some dissolved materials as well. Granular beds containing grains which are chemically coated with filter aid are excellent flocculation and adsorption devices as well as good strainers. The coarse-to-fine filter allows the use of finer media in the bottom of the filter than could be used satisfactorily in a single media bed because much of the solids load is removed in the coarse media in the top of the bed, and the presence of fine materials at the bottom thus does not involve high head losses. This also reduces the risk of solids leakage. The use of fine materials, 50 to 100 mesh, in the bottom of a mixed media bed as contrasted to the 30 to 50 mesh commonly used in the top of a sand filter, provides a much clearer filter effluent and at the same time greatly extends filter runs between backwashings.

At Tahoe, it was only when good mixed-media filter performance was demonstrated at pilot scale that consideration was given to full-scale advanced wastewater treatment. The subsequent ten years of development and experience in the operation of advanced treatment have reaffirmed and strengthened the importance of mixed-media filtration to the overall process. It should be emphasized that coarse media, deep-bed filtration is not equivalent to mixed-media filtration in terms of water quality produced. Process reliability also is not equivalent

Filter Role. A careful examination and evaluation of the role of coarse-to-fine filtration in overall treatment schemes reveals several important filter functions, including:

1. Coarse-to-fine filtration adds greatly to overall plant reliability in terms of continuous operation and consistent effluent quality. Solids carryover from secondary or chemical clarifiers or settling basins is stopped without harm to subsequent treatment units or process or interruption of normal operation. Even major surges of suspended solids can be handled by mixed-media filters without plant shutdown or sacrifice in effluent quality. Filtration is an excellent back up to overcome irregularities common to biological and chemical treatment.

2. Coarse-to-fine filtration produces water of exceptionally high clarity which can be accomplished in no other practical way. With use of a filter aid, any desired turbidity down to 0.05 J.U. (Jackson Units) can be maintained, although 0.2 to 0.3 J.U. are more realistic values for normal operation.

3. Filtration prior to granular carbon adsorption protects the carbon against fouling by suspended solids and colloidal matter and prevents loss of carbon efficiency upon regeneration due to the residual ash from incinerated solids. Prior filtration reduces the load of organics applied to the carbon and thus will permit either greater overall removals of organics with equal carbon contact time or shorter carbon contact time for the same removals. Overall economics generally favor the sequence of mixed-media filtration followed by carbon adsorption over combined filtration-adsorption in carbon beds with the required increased contact time.

4. The complete removal of suspended matter by filtration permits more effective disinfection of the water, in addition to the esthetic benefits realized from the production of a sparkling clear effluent.

How Mixed-Media Filters Act. The first concept necessary to understanding the performance of mixed-media filters is that mechanical straining is a relatively unimportant factor. Efficient filtration is a physical-chemical process involving particle destabilization and particle transport similar to the mechanisms of coagulation. Good coagulants are also efficient filter aids. The processes of coagulation and filtration are inseparable and the interrelationships must be considered for best treatment results. There are two basic approaches, (1) the coagulant dosage must be optimized for maximum filtrability rather than settleability of the floc produced, or, (2) a filter aid must be added to the filter influent to adjust the water to optimum filtrability. The second method is favored for wastewater treatment. The removal of suspended particles in a filter consists of at least two steps, (1) the transport of suspended particles to the solid-liquid surface of a grain of filter media or to another floc particle previously retained in the bed, followed by (2) the attachment and adsorption of particles to this surface. For filter runs of practical length, filter aid to coat filter grains must be added continuously (rather than pre-coated). When filter aids are used the filtration process is so effective that conventional sand or other surface filters clog very rapidly. Effective filtration without excessive head loss can be accomplished only by use of a coarse-to-fine, in-depth filter, such as a mixed-media filter. To differentiate this type of filter action (destabilization, attachment, and adsorption) from plain mechanical filtration by simple straining or surface filtration, mixed-media filters are commonly designated as separation beds.

For most lime treated wastewaters, a continuous feed of at least one to ten mg/l of alum is required to the filter influent as a filter aid. At times it may be desirable to also use 0.01 to 0.05 mg/l of Calgon ST-270, Purifloc N-11, or other similar polymer. For alum treated wastewaters 0.05 to 0.5 mg/l of ST-270 or other polymer may be required for best filtration results.

One important difference between coagulation and settling by flocculation versus filtration is the fact that the removal efficiency of a bed is independent of the applied concentration of particles while the time of flocculation is concentration dependent. Therefore, separation beds are capable of more effective and efficient removal of colloidal particles present in dilute but objectionable concentrations. The head loss developed during filtration is dependent upon media size, filtration rate, and the concentration of particles to be removed. Deep coarse beds or coarse-to-fine filters are required to avoid rapid and excessive head loss buildup.

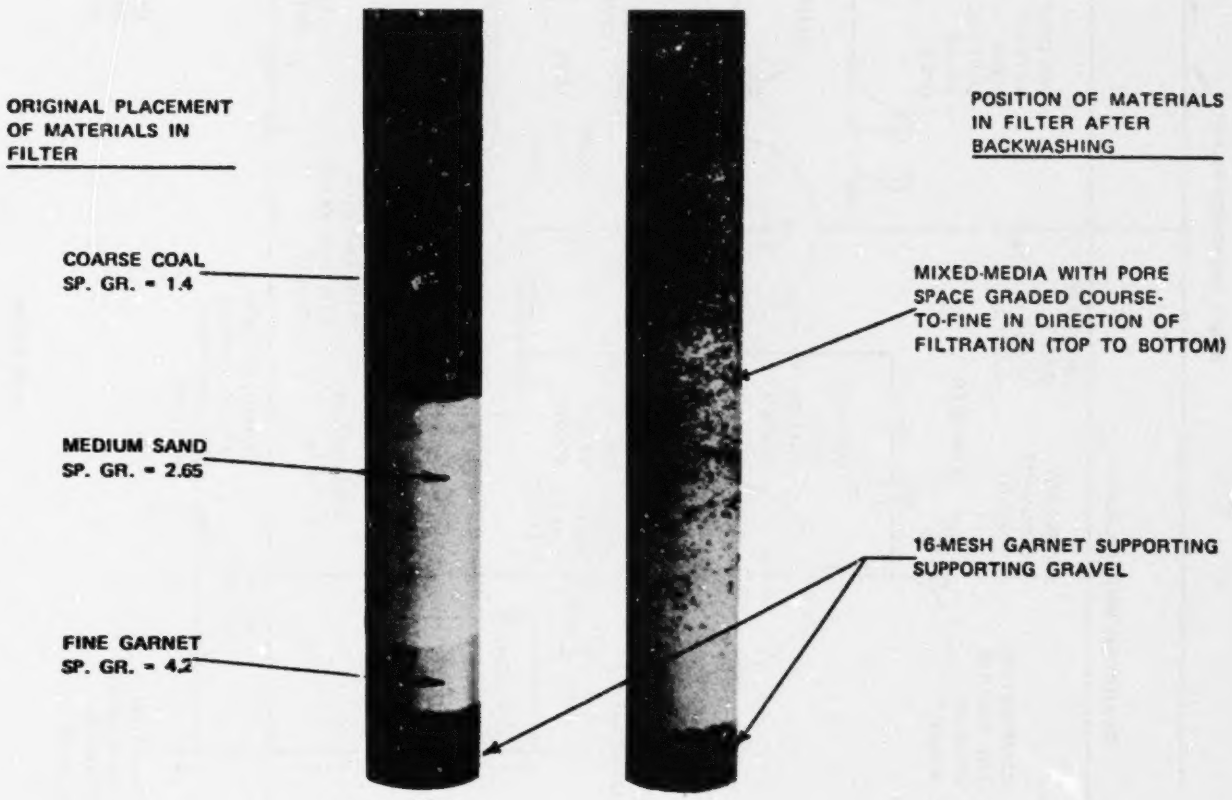
Separation Beds at South Tahoe. For the design flow of 7.5 mgd, there are three sets of two pressure beds in series, each 10 feet in diameter by 38 feet long. The design filter rate is 5 gpm/sf, but rates as high as 8 gpm/sf have been employed at full treatment efficiency. The backwash rate is 15 gpm/sf. Each pair of beds is washed as a unit in series. The surface wash consists of four 7-foot diameter rotary filter agitators per bed. Each bed consists of three feet of mixed-media (as supplied by Neptune Microfloc), supported on 3 inches of coarse garnet and 2 feet 4 inches of graded gravel.

Figure 53 shows a separation bed of fine media above a supporting layer of coarse garnet. The column on the left shows the original placement of layers of fine media, with coal at the top, sand in the center and fine garnet below. The column at the right shows the appearance of the bed after it has been hydraulically backwashed to produce the desired uniformly tapered coarse-to-fine pore space from top to bottom, the direction of flow during the filter cycle. Figure 54 shows the flow pattern for the filter cycle. The underdrains are perforated plastic pipe. The influent rate-of-flow controller consists of a Dall flow tube and a rubber-seated butterfly valve. Loss of head across each bed is continuously measured and recorded. Turbidity of separation bed effluent is continuously measured by a Hach CR Turbidimeter to tenths of a JU (Jackson Unit) and recorded. All filter operations are fully automatic. Backwash may be initiated by time clock, high head loss, high turbidity, or manually. The manual mode is used most of the time. The beds are backwashed, filtered to waste, and restored on line automatically by a program timer. The filters are backwashed with filter influent water by means of a pump. There is a pressure-booster pump for surface wash supply. Waste wash water discharges into an 80,000 gallon steel tank (which holds the water from 2 backwashes). The water from this tank is returned to the treatment process slowly over a period of about two hours. One pair of these beds has been in service for five years, and the other two pairs have been in use for three years at this writing (1971).

All except one end of each bed is installed out-of-doors. An allowance was made in the design for the formation of 4 inches of ice inside the steel filter shell. This ice then insulates the tank against further freezing under conditions of normal water flow through the bed. An exterior view of the separation beds, decanting tank, and tertiary building is presented in Figure 55.

FIGURE 53

MIXED MEDIA FILTER BEFORE AND AFTER INITIAL BACKWASHING


ORIGINAL PLACEMENT OF MATERIALS IN FILTER
COARSE COAL SP. GR. = 1.4
MEDIUM SAND SP. GR. = 2.65
FINE GARNET SP. GR. = 4.2
POSITION OF MATERIALS IN FILTER AFTER BACKWASHING
MIXED-MEDIA WITH PORE SPACE GRADED COURSE-TO-FINE IN DIRECTION OF FILTRATION (TOP TO BOTTOM)
16-MESH GARNET SUPPORTING SUPPORTING GRAVEL

NOT REPRODUCIBLE

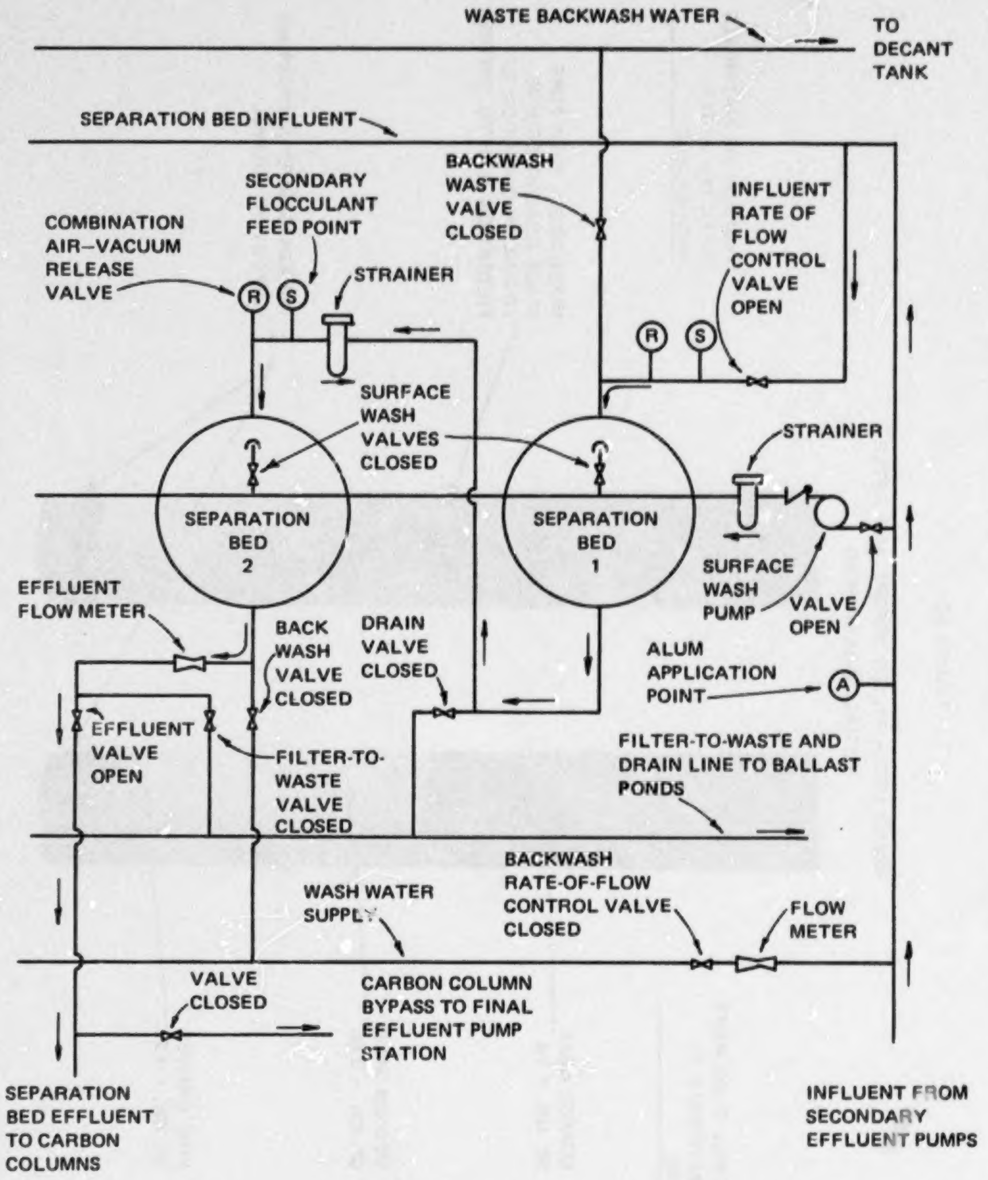

WASTE BACKWASH WATER
TO DECANT TANK
SEPARATION BED INFLUENT
BACKWASH WASTE VALVE CLOSED
SECONDARY FLOCCULANT FEED POINT
COMBINATION AIR–VACUUM RELEASE VALVE
R
S
STRAINER
INFLUENT RATE OF FLOW CONTROL VALVE OPEN
R
S
SURFACE WASH VALVES CLOSED
STRAINER
SEPARATION BED 2
SEPARATION BED 1
SURFACE WASH PUMP
VALVE OPEN
EFFLUENT FLOW METER
BACK WASH VALVE CLOSED
DRAIN VALVE CLOSED
ALUM APPLICATION POINT
A
EFFLUENT VALVE OPEN
FILTER-TO-WASTE VALVE CLOSED
FILTER-TO-WASTE AND DRAIN LINE TO BALLAST PONDS
WASH WATER SUPPLY
BACKWASH RATE-OF-FLOW CONTROL VALVE CLOSED
FLOW METER
VALVE CLOSED
CARBON COLUMN BYPASS TO FINAL EFFLUENT PUMP STATION
SEPARATION BED EFFLUENT TO CARBON COLUMNS
INFLUENT FROM SECONDARY EFFLUENT PUMPS

FIGURE 54

SEPARATION BEDS
FILTER CYCLE

NOT REPRODUCIBLE

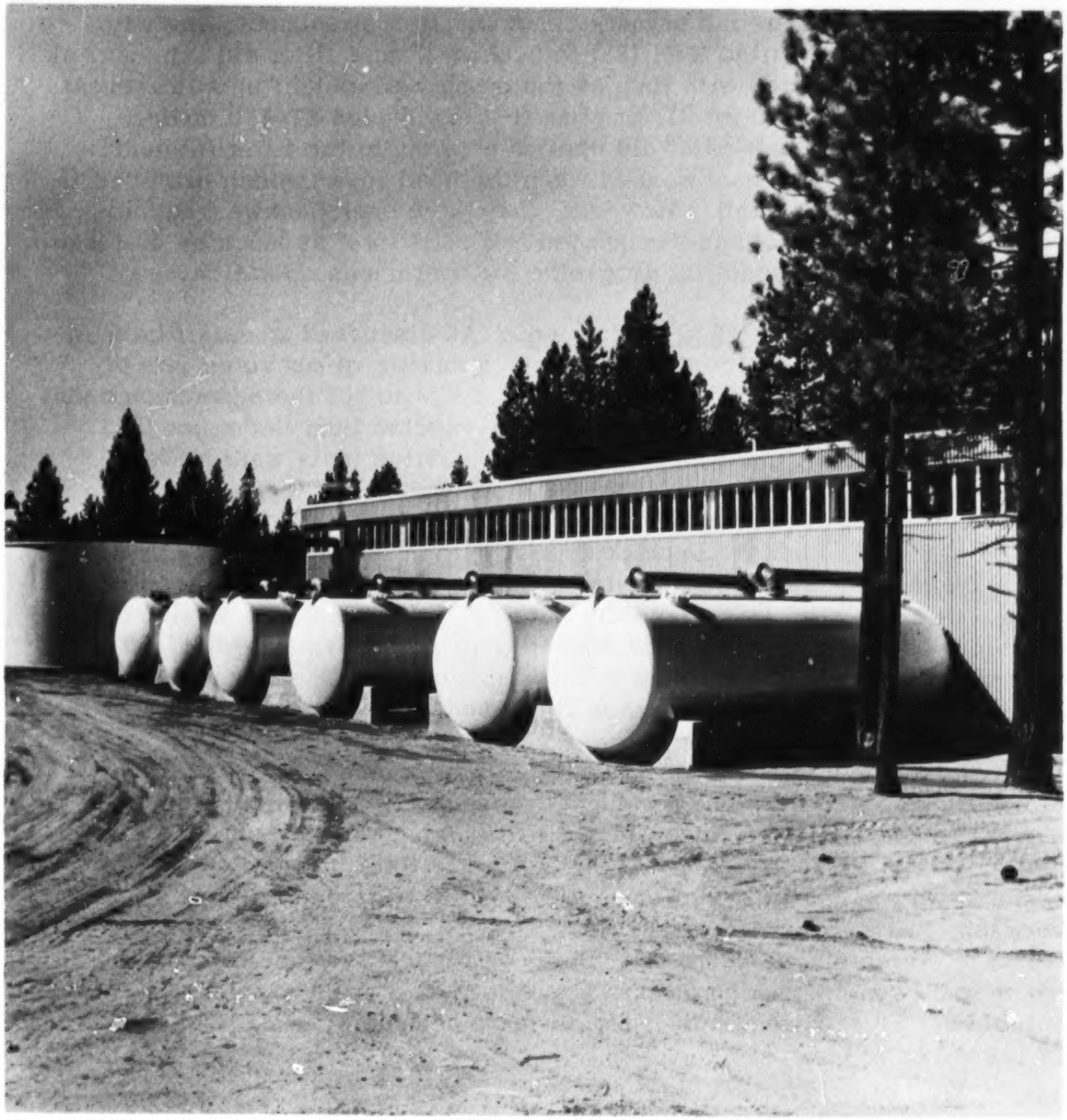


Figure 55

EXTERIOR VIEW OF SEPARATION BEDS, DECANTING TANK AND TERTIARY BUILDING

The performance of these beds and the control system has been excellent. The length of filter runs vary from 4 hours under very bad conditions to about 60 hours under good conditions. At one time they were used with alum as the primary coagulant in pretreatment, and with Calgon ST-270 or Purifloc N-11 (0.1 to 0.8 mg/l) as a filter aid. In normal operation they are used with lime as the primary coagulant in pretreatment and either alum (1 to 20 mg/l), or alum (1-2 mg/l) plus ST-270 or N-11 (0.01 to 0.10 mg/l) as a filter aid applied directly to the filter influent. Normally the beds are backwashed when the head loss through each bed is about 8 feet (16 feet total). However, they have been backwashed successfully after head losses through the two beds total as much as 40 feet. This high head loss would be excessive for continuous operation.

Special Separation Bed Evaluation. As discussed in detail later in this report under Plant Operation Results, a number of measurements of performance were made at all times during operation of the separation beds. In addition, during a special four month test period from December 1969 through March 1970, more intensive and exhaustive tests were made to evaluate separation bed capabilities and performance. The removals of some substances are shown in Table 21.

Two approaches were used in collecting the data during the special tests. One approach was to collect data on daily operations having the operators control alum feed according to their personal judgement. Samples of bed influent and effluent were composited for 24 hours and analyzed. Total daily flow and amount of alum used were recorded.

The second approach was to collect data across one specific pair of beds. For each test run the alum dosage was fixed at a constant rate and the run was allowed to continue until a high turbidity (2.0 SJU) or high headloss (15 ft lead bed) alarm sounded to terminate the run. Grab samples were taken from the influent to the two beds operating in series, between the two beds and after the second bed. The samples of each run were collected two hours after the beginning of the run. In addition to the analyses and measurements previously described, particulate and soluble PO_4-P, and length of filter run were measured. Results are shown in Table 22.

TABLE 21

Typical Removals by the Separation Beds For Test Period - March 11 - April 5, 1970

AVERAGE CONCENTRATIONS
mg/l

	Influent	Effluent	Removals, Percent	
			Range	Average
PO_4-P, Total	.57	.10	57-99.5	82
COD	32.7	21.2	14-50	35
BOD	8.2	3.8	27-77	54
Suspended Solids	9	1.3	68-100	86
Hardness as $CaCO_3$	157	150		
Turbidity SJU	5.6	0.4	80-95	93

TABLE 22

Removal Efficiencies of Two Separation Beds in Series at 8 - 64 ppm Dry Alum Dosages for Test Period - Nov. 69 to Mar. 70

Substance	Average % Removal Across Lead Filter	Average % Removal Across Second Filter	Range of % Removal Across Second Filter
PO_4-P Total	79	4	0 - 13
PO_4- Soluble	78	3	0 - 12
PO_4- P Particulate	86	5	0 - 16
COD	30	7	1 - 17
BOD	57	13	6 - 24
SS	80	19	0 - 50
Turbidity	78	10	2 - 30

Test Results - Separation Bed Evaluation. The flow rates to the beds varied between 2.8 gpm/ft^2 and 4.0 gpm/ft^2, on an average daily basis. Within this flow range, the removal efficiencies for phosphorus, COD, BOD, suspended solids and turbidity were not affected.

Total removal efficiency across both beds dropped considerably at zero alum dosage for all substances measured except suspended solids. Across the second bed, at no alum dosage, particulate PO_4-P showed much higher than average removal efficiencies.

In the range of 8-64 mg/l dry alum dosage, total and soluble PO_4-P and total COD removal showed slight variation with alum dosage. COD and soluble PO_4-P removal efficiency increased slightly with increasing alum dosage whereas total PO_4-P appeared to decrease slightly. The variations in removal efficiencies with alum dosage for total PO_4-P, soluble PO4-P, COD, and BOD are shown in Figures 56, 57, 58 and 59, respectively.

The additional filter depth provided by the second separation bed has been extremely useful during periods of higher solids loadings. The second filter has permitted the plant to achieve near 100% suspended solids regardless of treatment efficiencies upstream. During the test period when the headloss or turbidity alarms were used to terminate the test run, the second filter was needed to reduce suspended solids concentrations to zero when influent loadings to the first filter were greater than 5-6 mg/l suspended solids.

As indicated earlier, alum feed concentration between 8-64 mg/l did not appear to greatly affect removal efficiencies; however, on waters with similar solids loadings, increasing alum feed concentrations decreased length of filter run. Figure 60 shows such an effect. Each of the filter runs shown in Figure 60 were terminated by a headloss alarm, except the 18 mg/l suspended solids influent loading, which was terminated by turbidity of 2.0 SJU. A test run of 6 mg/l suspended solids with no alum dosage lasted about five hours. This run was also terminated by turbidity of 2.0 SJU.

It is suspected that most of the influent suspended solids were algae cells from the ballast ponds. The suspended solids prior to volatilization were slightly green on the filter pad. Tests showed that the suspended solids were completely volatile.

FIGURE 56

PERCENT REMOVAL OF PO_4-P VS DRY ALUM DOSAGE ACROSS BOTH SEPARATION BEDS

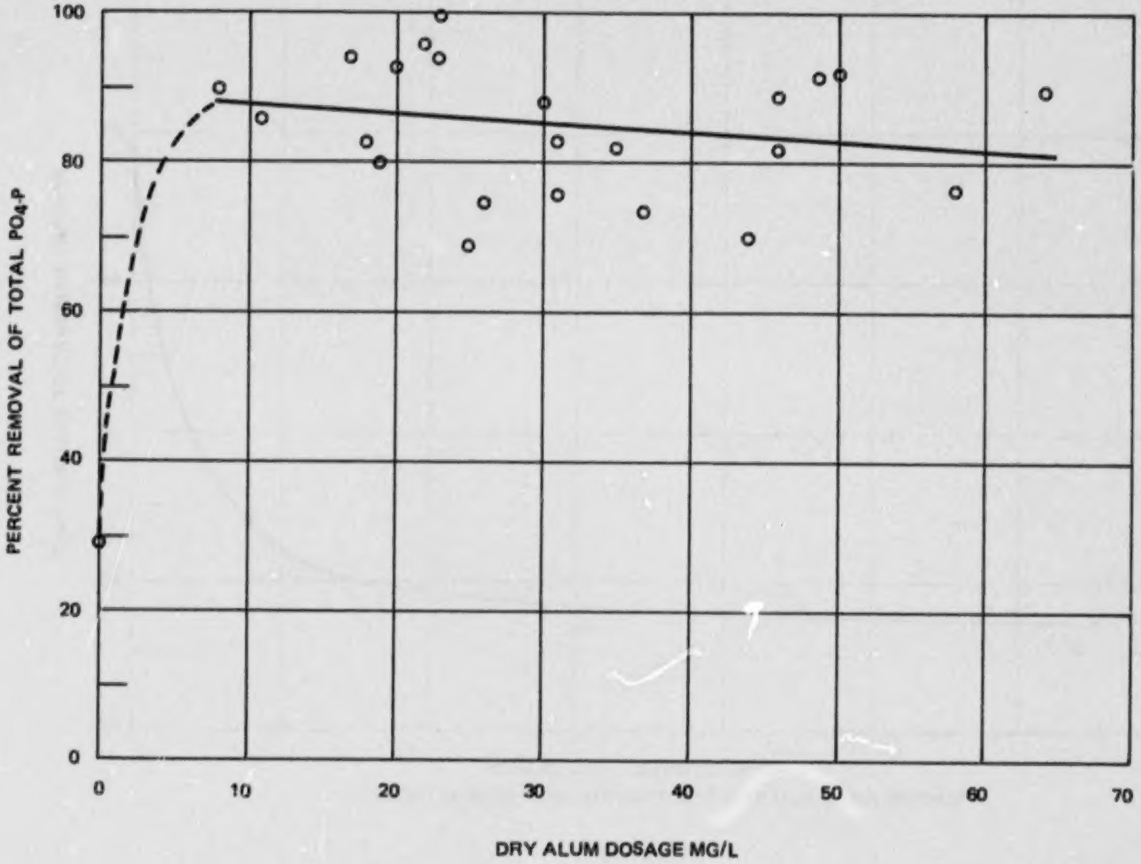


FIGURE 57

PERCENT REMOVAL OF SOLUBLE PO_4-P VS DRY ALUM DOSAGE
ACROSS BOTH SEPARATION BEDS

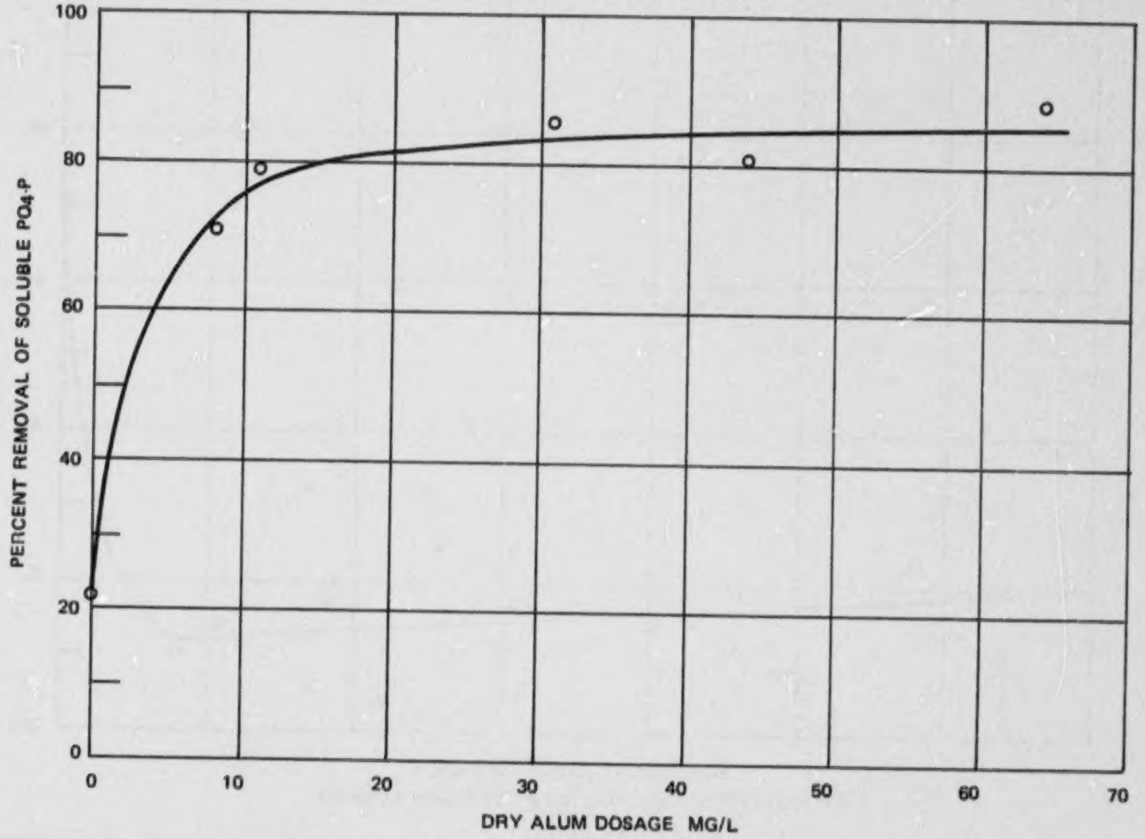


FIGURE 58

PERCENT REMOVAL OF COD VS DRY ALUM DCSAGE
ACROSS BOTH SEPARATION BEDS

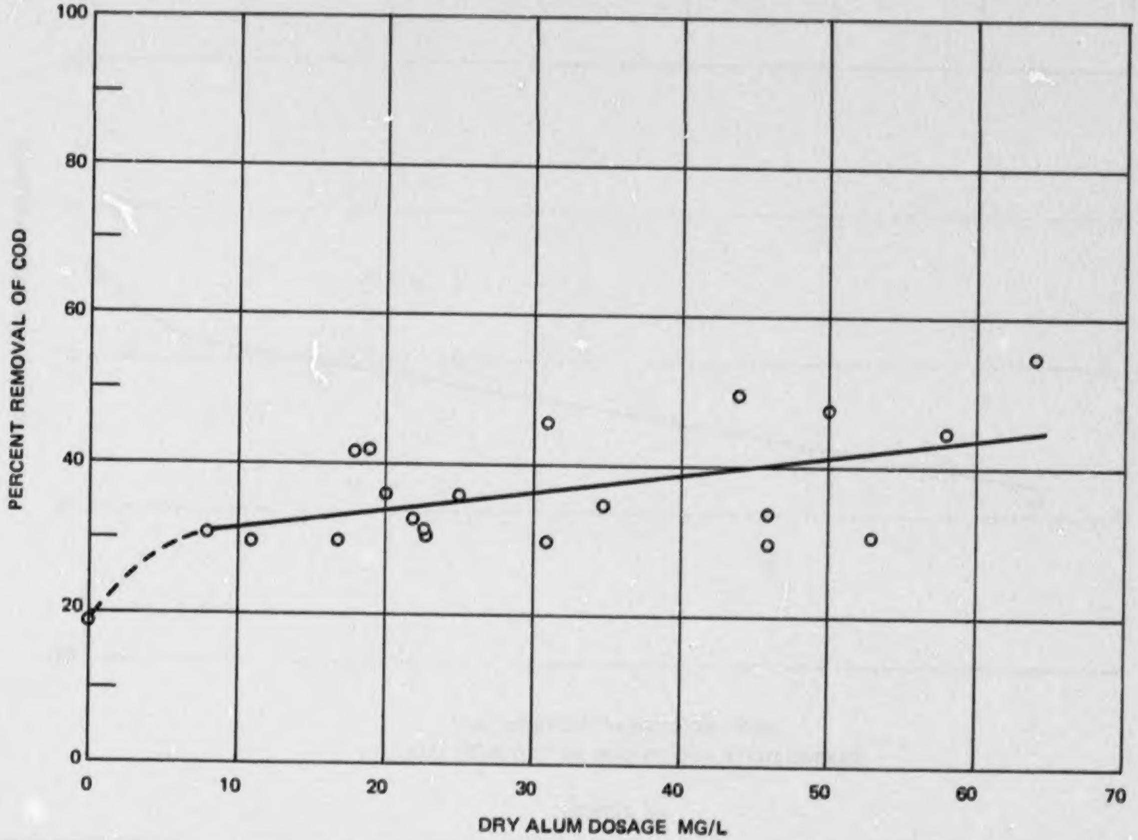


FIGURE 59

PERCENT REMOVAL OF BOD VS DRY ALUM DOSAGE
ACROSS BOTH SEPARATION BEDS

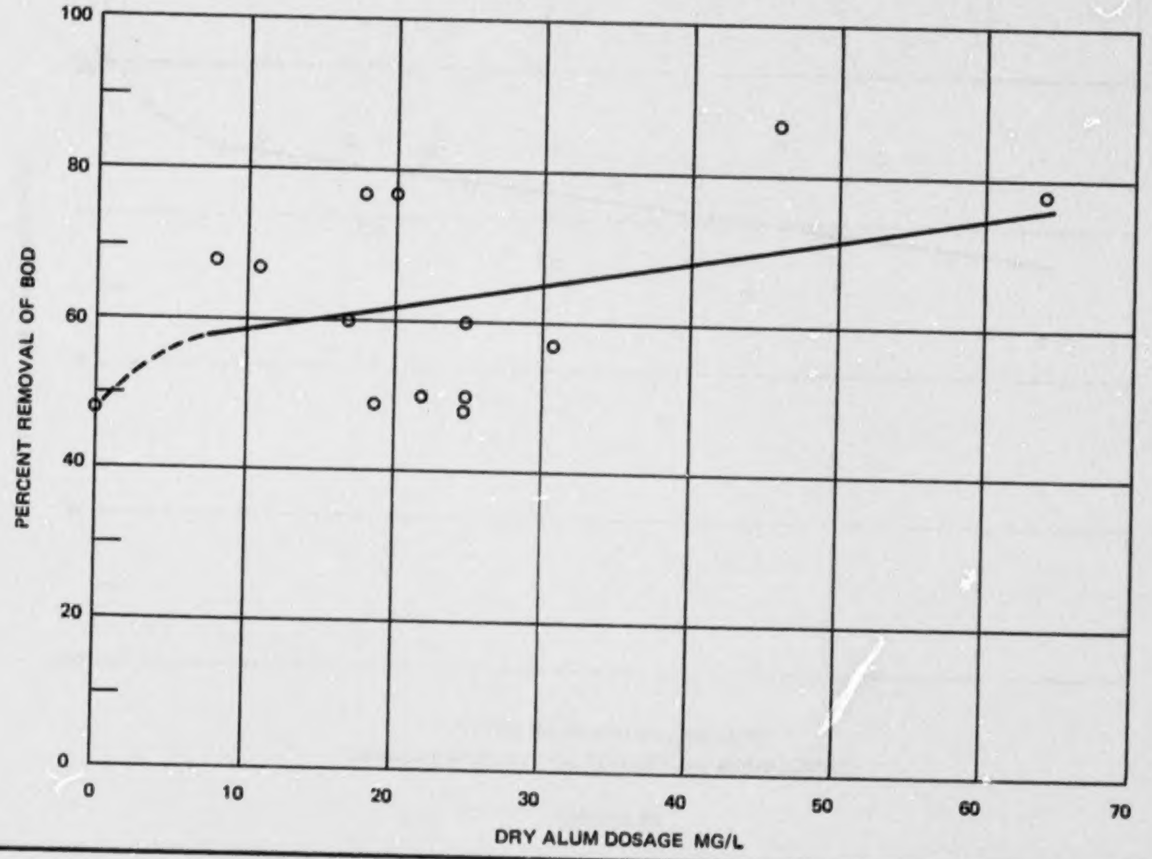


FIGURE 60

LENGTH OF SEPARATION BED RUN
VS DRY ALUM DOSAGE

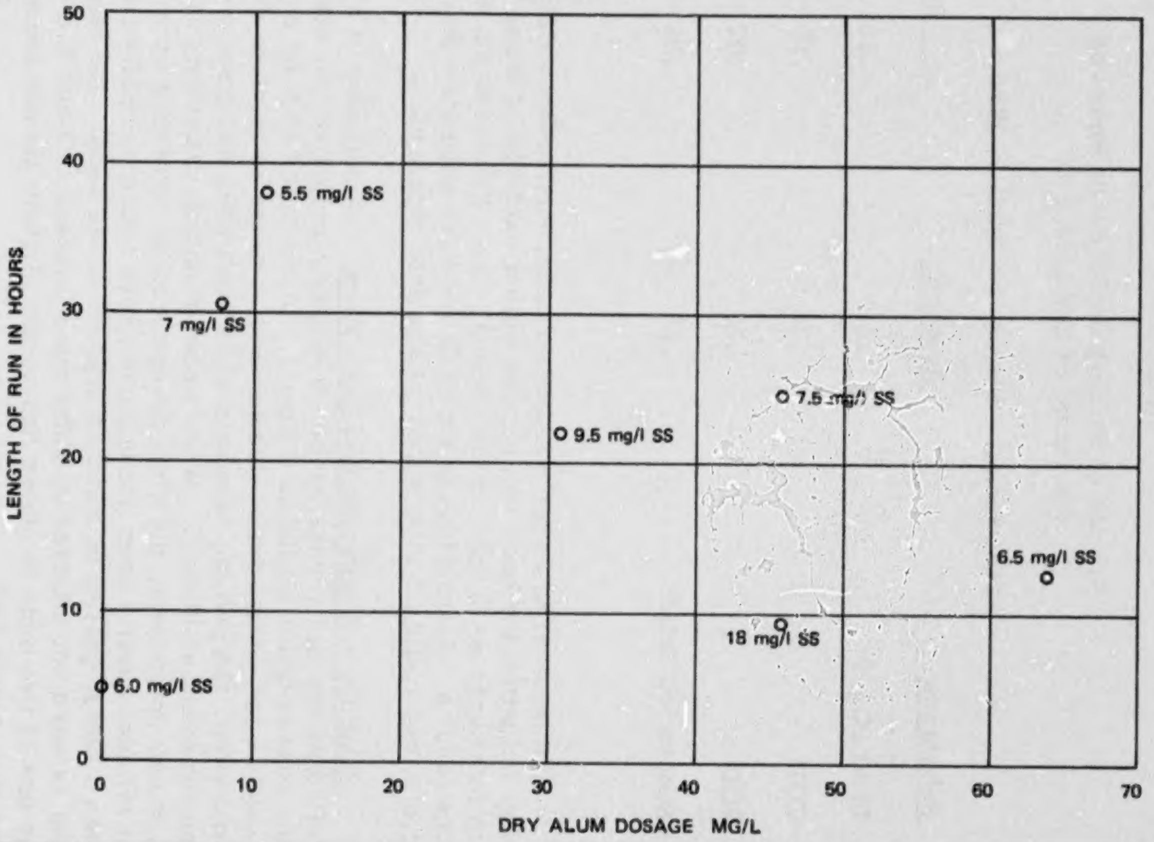


Table 23 shows the pounds removed of various substances by the filters for each pound of dry alum fed.

TABLE 23

Pounds of Various Susbstances Removed
Per Pound of Dry Alum Fed

Test Period - March 11 - April 5, 1970

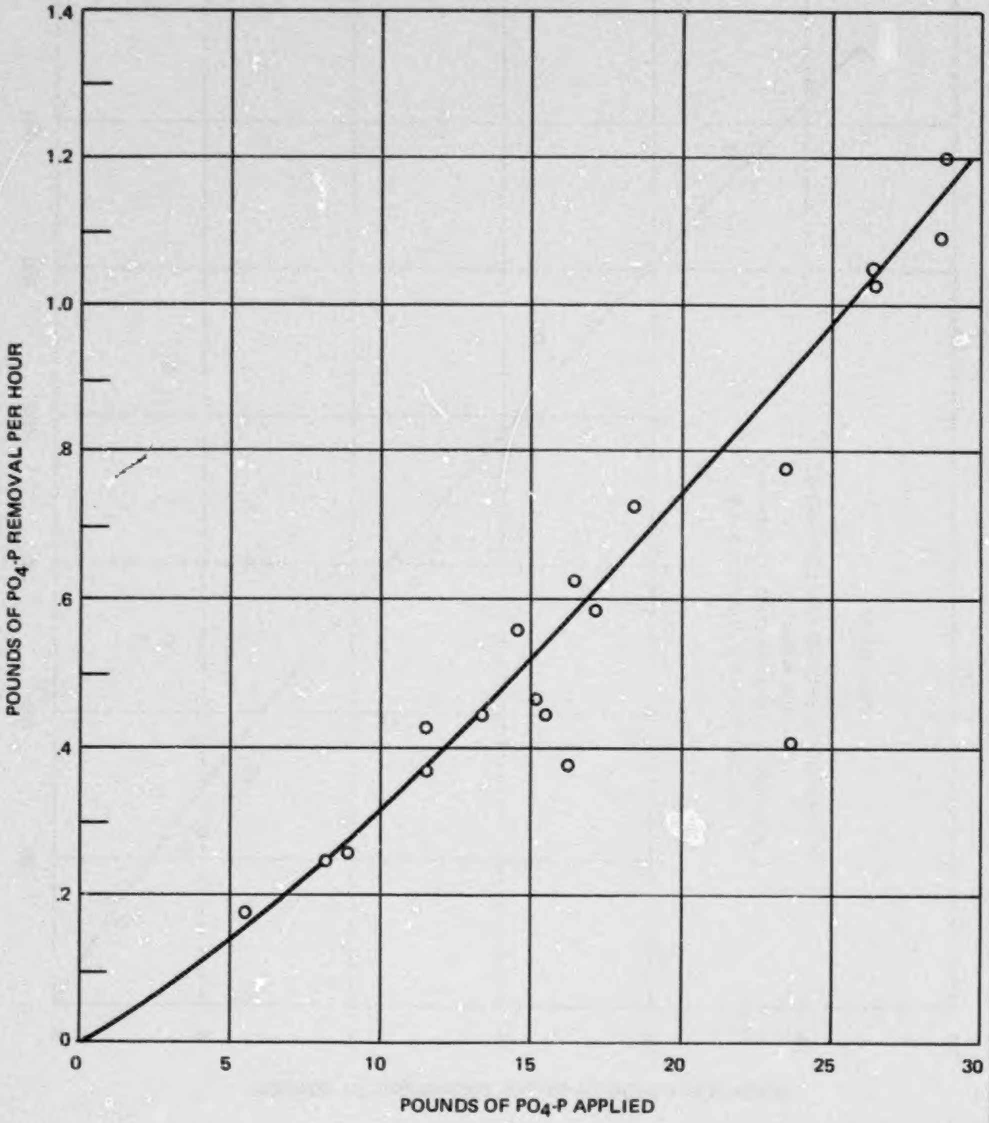
Substance	Average	Range
Total PO_4-P	.019	.003 - .037
COD	.36	.15 - .51
BOD	.22	.02 - .37
Suspended Solids	.28	.06 - 1.12

The removal rates for orthophosphorus, suspended solids, and turbidity indicated the beds can remove higher loadings of these paramenters with relatively no change in the removal rate. Figures 61,62, and 63 show these results. Removal rates for COD and BOD were very erratic and no correlations could be interpreted for the data obtained.

Summary - Separation Bed Evaluation. A summary of all parameters studied during the separation bed evaluation indicated the optimum dry alum dosage to be around 15-25 mg/l. In the range of 0-64 mg/l alum dosages used during the evaluation and in those parameters showing a correlation, the percent removals at 60 mg/l were not greatly different than removals at 10 mg/l. When water of poorer filtrability is encountered in bed operations, the alum dosage may be increased up to 30-50 mg/l, but effluent quality does not improve above levels normally encountered when a better quality of water is applied to the beds. The removal efficiencies were not affected by filter rates between 2.8 and 4.0 gpm/ft^2. The use of two beds in series has shown slightly greater removal efficiencies than single bed.

FIGURE 61

POUNDS OF PO_4-P REMOVED PER HOUR VS POUNDS OF PO_4-P APPLIED ACROSS BOTH SEPARATION BEDS



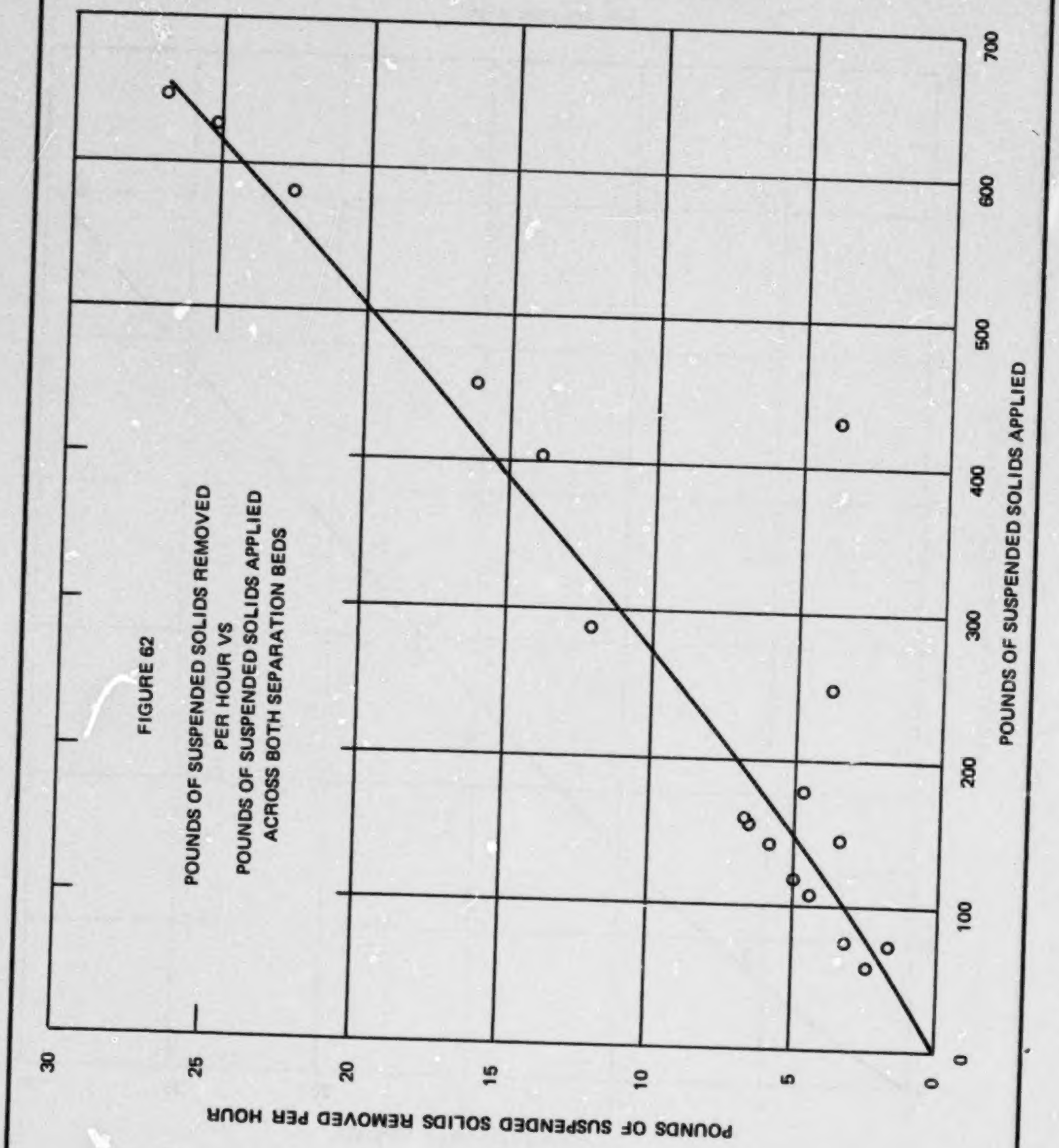
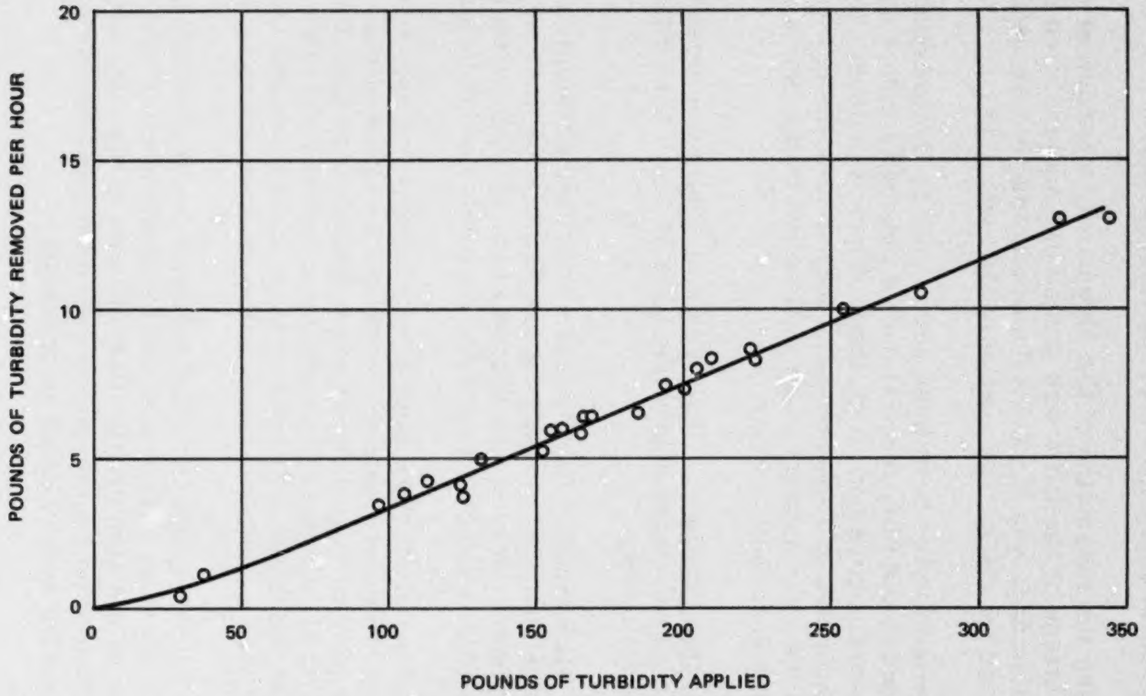


FIGURE 62

POUNDS OF SUSPENDED SOLIDS REMOVED PER HOUR VS POUNDS OF SUSPENDED SOLIDS APPLIED ACROSS BOTH SEPARATION BEDS

FIGURE 63

POUNDS OF TURBIDITY (1) REMOVED PER HOUR
VS POUNDS OF TURBIDITY APPLIED ACROSS
BOTH SEPARATION BEDS



(1) ASSUMING 1 SJU = 1 MG/1

In November 1969 the six beds were opened for electrical maintenance on the surface wash arms. At this time the surface of the filter media was examined for calcium carbonate buildup. From visual examination there appeared to be no buildup of calcium carbonate on the media. Further, no hardness reduction was noted across the beds. Two of these beds had been in operation since the summer of 1966.

During the inspection of the oldest set, a sample of sand and coal from the surface of the filter was ground up, and analyzed for calcium oxide. The available CaO was 0.6%. A duplicate sample was calcined at 1800°F and analyzed for CaO. The available CaO was 1.1%.

Polyelectrolytes have been used, only in limited quantities, in the past to improve turbidity removal during unusually high solids loadings and subsequent above normal numbers of backwashings. However, from the past two years of experience and from data collected thus far, alum applied to the beds appears to be well suited to the needs of the South Tahoe Water Reclamation Plant.

Filtration Summary. Five years of continuous operation of full plant scale mixed-media separation beds at South Lake Tahoe have demonstrated the following:

1. Mixed-media filtration is a reliable, efficient, easily controlled and economical process for clarification of wastewater. Suspended solids can be removed to a degree which will permit reclaimed water to be used for the first time for many purposes not heretofore possible.

2. Separation beds exert a very important stabilizing effect upon the entire wastewater treatment process. By virtue of the ability of separation beds to remove suspended and colloidal materials from applied water, even with rapid, sizeable fluctuations in influent turbidities, upsets in the operation of preceding settling basins or other treatment units can be handled without loss in filtered water quality or interruption in treatment.

3. Mixed-media filtration produces water of exceptionally low turbidity (0.05 to 0.3 JU) which can be obtained in no other practical way. Application of the high clarity filter effluent to granular carbon affords maximum protection for the carbon against fouling and loss of efficiency, and disinfection with chlorine is enhanced.

4. Visual inspection of the beds and laboratory tests of the media both indicate that the filter beds are still in excellent condition after 5 years of continuous full time service.

5. The automatic filter controls perform very well and are quite reliable.

SECTION XX

GRANULAR ACTIVATED CARBON ADSORPTION AND REGENERATION.

The most important process at the Tahoe plant in terms of meeting the stringent export requirements is the granular activated carbon adsorption of dissolved organics and detergents. Since thermal regeneration of the granular activated carbon is necessary to operate the adsorption process most economically, and to facilitate and clarify the data collection results, the two processes of adsorption and regeneration will be discussed together.

The first portion of this section describes the particular physical system and operating practices for the carbon adsorption and regeneration processes used at the water reclamation plant during the grant period. Following a description of the sampling program and methods of data collection during the grant period, there is a general discussion of the gross loadings and operating parameters for the adsorption and regeneration systems. Finally, in reference to the grant requirements, there are specific discussions concerning removal of organics over several carbon regenerations, adsorption contact time, regeneration efficiency, inert material build-up in the carbon, and carbon losses due to regeneration and physical handling.

Carbon Adsorption System. The purpose of the activated carbon adsorption system is the removal of dissolved organics from the separation bed effluent to insure that the reclaimed water meets the stringent export standards for Chemical Oxygen Demand, Biochemical Oxygen Demand, and Methylene Blue Active Substances (Detergents).

The adsorption system includes eight carbon columns which operate in parallel, each as upflow (countercurrent) columns in normal service. Fig. 64 shows four of these columns. Flow may be reversed for flushing the top screens, compacting the carbon bed or removing matter in the lower section of the column. Any or all of the carbon columns may be bypassed. Effluent from the carbon columns normally passes on to disinfection and the final effluent pump station, but may be diverted to the ballast ponds, if desired. The valve positions for normal upflow operation of the

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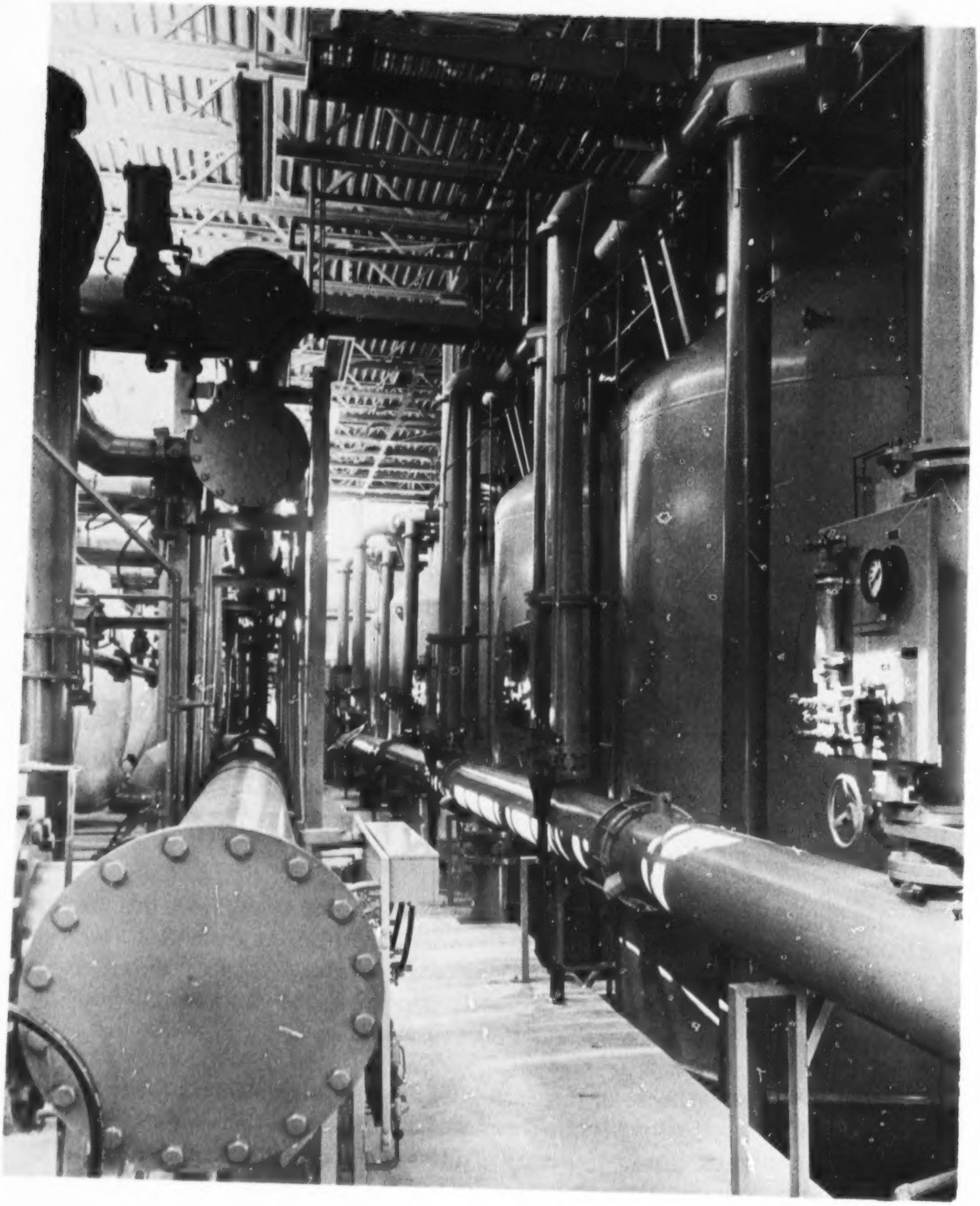


Figure 64

CARBON COLUMNS

NOT REPRODUCIBLE

carbon columns are shown in Figure 65. The valves are manually operated. The flow rate through each carbon column is set by manual operation of a butterfly valve on the carbon column discharge line. There is flow indication at this control valve location.

The separation bed effluent flows under pressure into the column through a series of eight, 12-inch diameter, stainless steel well screens located on the periphery of the column at the bottom (Figure 66). In a similar fashion the column effluent leaves the column through well screens located at the top of the column. The system is designed to approach a true counter current moving bed process at design flows, but at present flows the carbon is withdrawn from the bottom, regenerated, and added to the top of the columns on a batch basis. This method of operation makes possible complete exhaustion of the carbon before withdrawal, as well as final passage of the effluent over freshly regenerated carbon.

Each of the eight 12-foot diameter by 24 high steel columns contain approximately 1600 to 1700 ft^3 (24-26 tons) of 8 X 30 mesh granular activated carbon. In all considerations, the specific gravity of the carbon was assumed to be 30 lbs/ft^3. The carbon type is Filtrasorb 300, a product of the Calgon Corporation. The effective carbon bed depth in the columns is 14 feet, and the cross-sectional area is 113 $feet^2$. The design flow rate through the columns of 735 gpm provides a 17 minute superficial contact time, and a hydraulic loading of approximately 6.5 gpm/ft^2.

Carbon Regeneration System. Thermal regeneration of the granular carbon is required to make the adsorption process economically feasible. Figures 67 and 68 depict the regeneration system at South Lake Tahoe.

A slug of spent carbon is withdrawn in a water slurry and transferred to a dewatering bin where the transfer water is allowed to drain off. Each column is fitted with peripheral water jets at the bottom to insure uniform withdrawal of the spent carbon.

The dewatering bin has a variable speed conveyor at the bottom, in which the carbon is augered into the top hearth of a six hearth furnace. The furnace is 4.5 ft in diameter and can operate at feed rates from 1000-6000 lbs. per day. Regeneration temperatures range from 1650° to 1750°F, with natural gas as the heat source. Regeneration is accomplished in a limited oxygen atmosphere with the addition of steam to produce more uniform temperatures on each hearth and better carbon regeneration. Organic impurities in the carbon are volatized and driven off in gaseous form. The furnace is provided with an afterburner and a wet scrubber to control exhaust emissions. In the carbon regeneration furnace, the carbon flows downward through the six hearths in series. The hearths are numbered 1 to 6 from top to bottom. Burners are located on hearths 4 and 6 and are

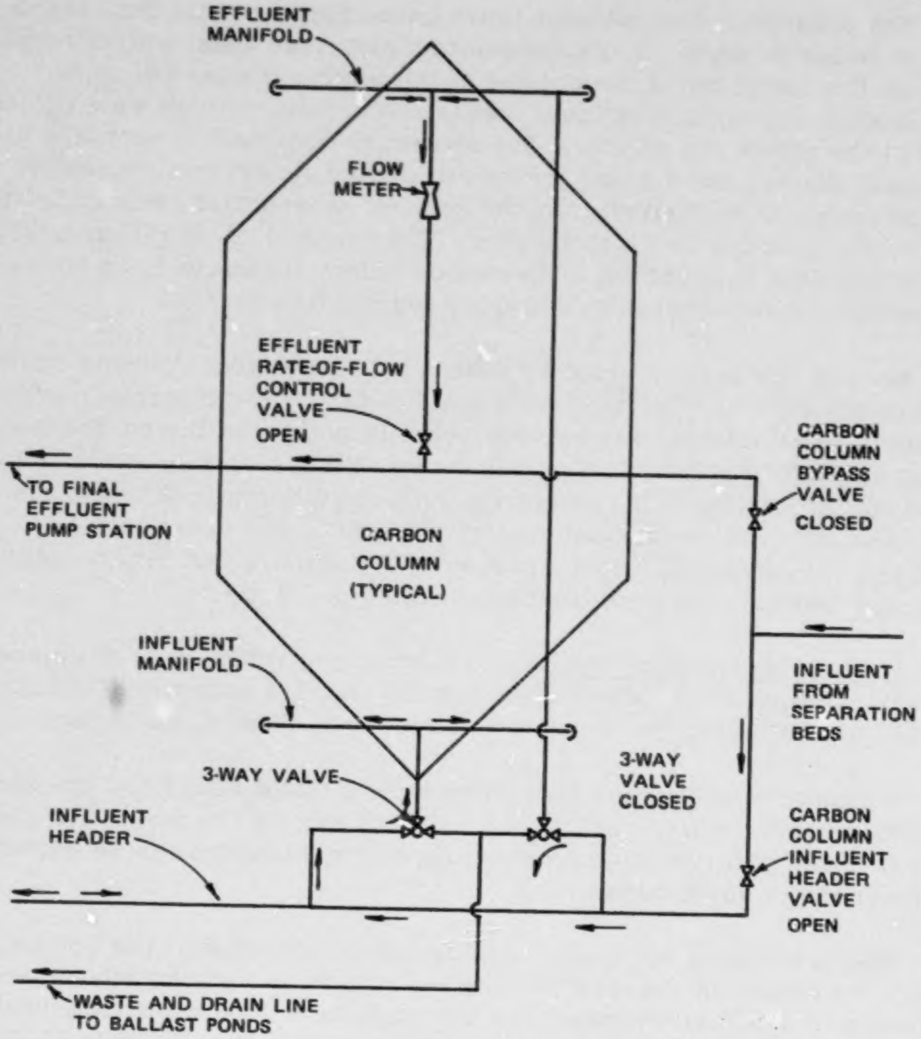

EFFLUENT MANIFOLD
FLOW METER
EFFLUENT RATE-OF-FLOW CONTROL VALVE OPEN
TO FINAL EFFLUENT PUMP STATION
CARBON COLUMN BYPASS VALVE CLOSED
CARBON COLUMN (TYPICAL)
INFLUENT FROM SEPARATION BEDS
INFLUENT MANIFOLD
3-WAY VALVE
3-WAY VALVE CLOSED
INFLUENT HEADER
CARBON COLUMN INFLUENT HEADER VALVE OPEN
WASTE AND DRAIN LINE TO BALLAST PONDS

FIGURE 65

CARBON COLUMNS
NORMAL UPFLOW OPERATION

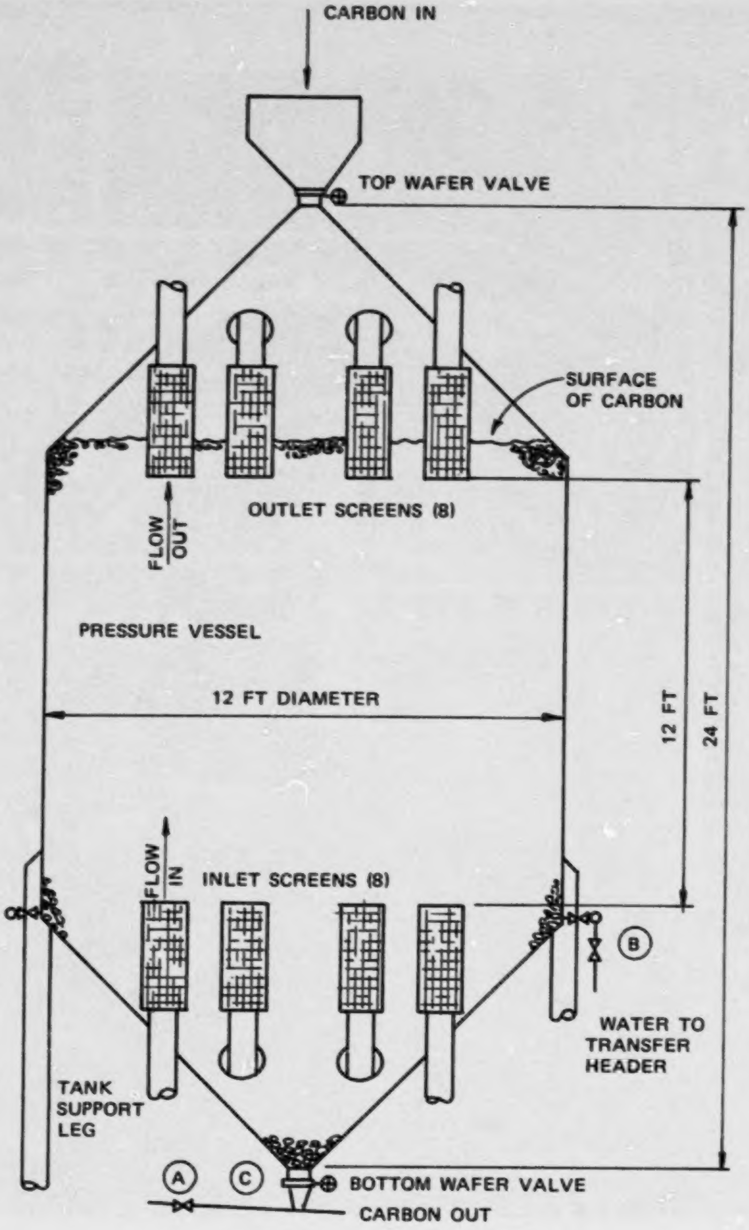

CARBON IN
TOP WAFER VALVE
SURFACE OF CARBON
OUTLET SCREENS (8)
FLOW OUT
PRESSURE VESSEL
12 FT DIAMETER
12 FT
24 FT
FLOW IN
INLET SCREENS (8)
B
WATER TO TRANSFER HEADER
TANK SUPPORT LEG
A
C
BOTTOM WAFER VALVE
CARBON OUT

FIGURE 66

SECTION THRU CARBON COLUMN

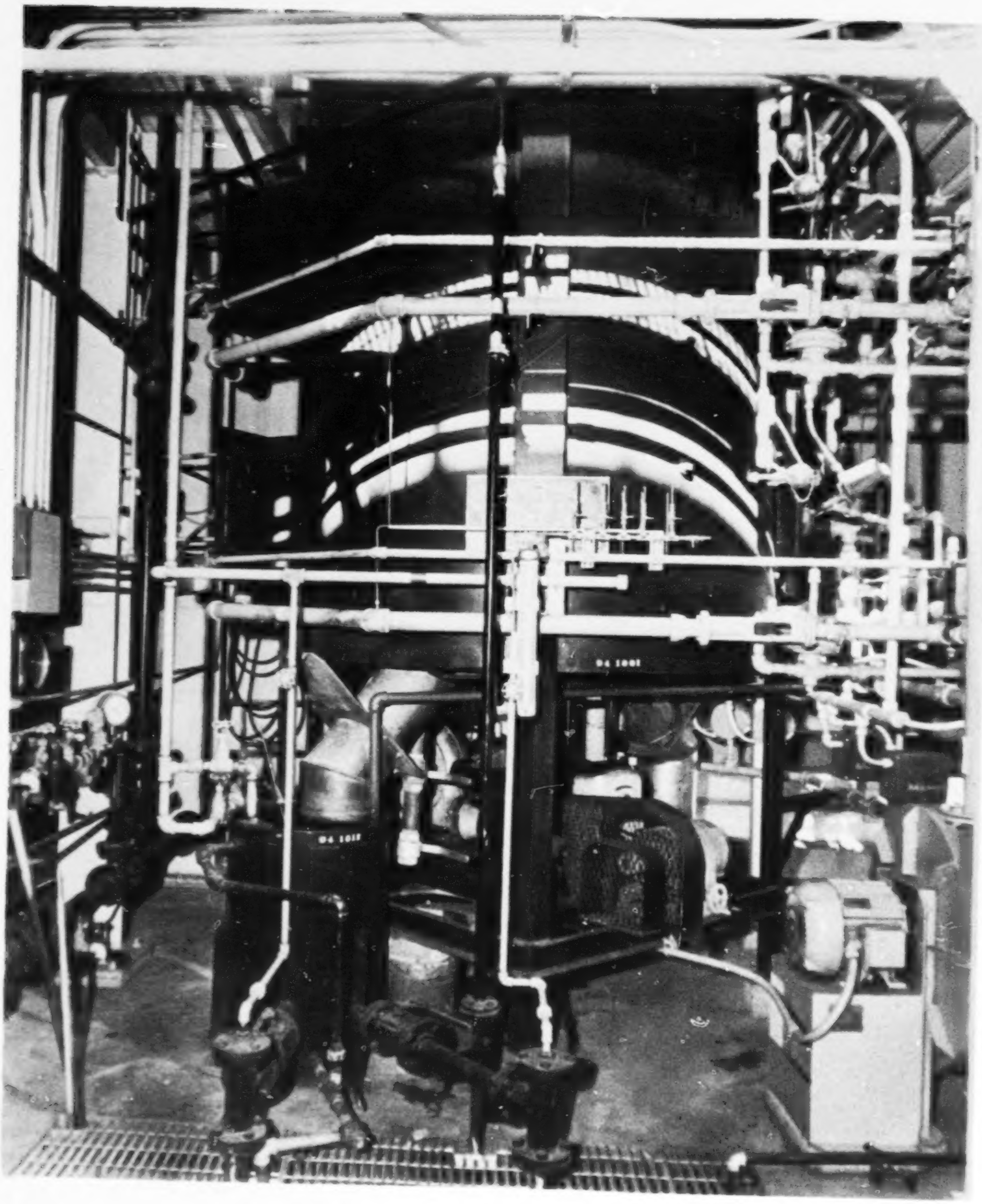


Figure 67

CARBON FURNACE AND QUENCH TANK

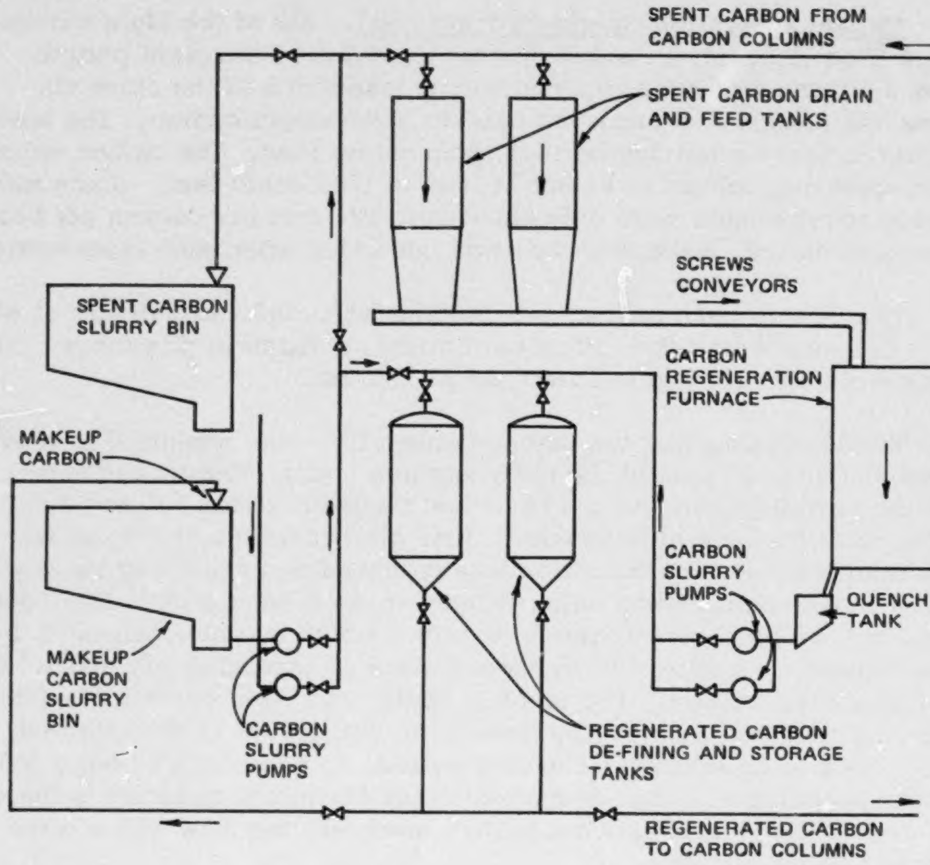

SPENT CARBON FROM
CARBON COLUMNS
SPENT CARBON DRAIN
AND FEED TANKS
SPENT CARBON
SLURRY BIN
SCREWS
CONVEYORS
CARBON
REGENERATION
FURNACE
MAKEUP
CARBON
CARBON
SLURRY
PUMPS
QUENCH
TANK
MAKEUP
CARBON
SLURRY
BIN
CARBON
SLURRY
PUMPS
REGENERATED CARBON
DE-FINING AND STORAGE
TANKS
REGENERATED CARBON
TO CARBON COLUMNS

FIGURE 68

CARBON REGENERATION SYSTEM

equipped with automatic temperature controllers. The steam is supplied to hearths 4 and 6.

The regenerated carbon is cooled in a quench tank and pumped by an air diaphram slurry pump to carbon defining tanks. The carbon is washed in the tanks to remove carbon fines produced in the regeneration and transportation. After defining the tank is pressurized and the carbon is transferred in a slurry back to the top of the column. The defining tank is shown in Figure 69.

Carbon Adsorption Operating Practices. Six of the eight carbon columns (Nos. 1, 2, 4, 5, 6 and 8) were used during the grant period. Number 3 column was kept empty to permit inspection of the other six columns and number 7 column was used to store virgin carbon. The seventh column except for holiday periods received no flow. The carbon volume in each operating column was kept at 1600 to 1700 cubic feet. Since makeup carbon requirements were only about 20 cubic feet per column per batch regeneration period, makeup carbon was not added after each regeneration.

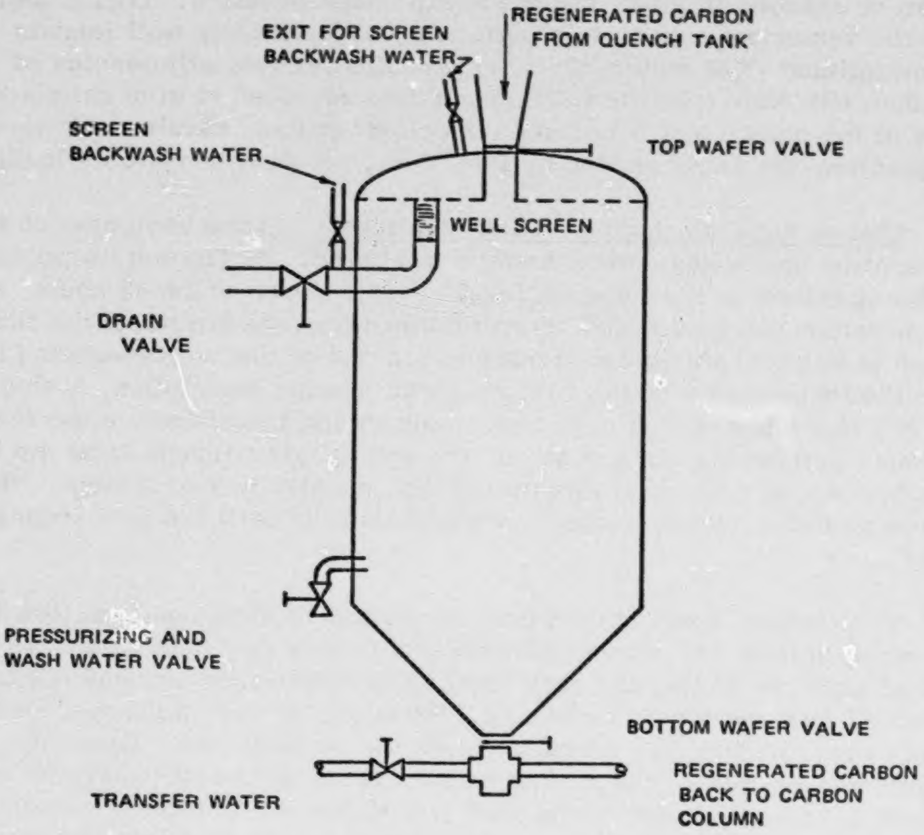
The flow to each column was held between 500 and 735 gpm at all times. Columns were taken off or put on line to maintain this range. The columns were also rotated to insure equal loading.

For several months the carbon column flow was permitted to range between 200 and 500 gpm in the early morning hours. During the same period the turbidity going on to the carbon ranged between 1.5 and 2.5 Jackson Units for several days due to lime clarification and CO_2 production difficulties. Hydrogen sulfide was produced and some mud balls were observed in the spent carbon being withdrawn for regeneration. The odor and mud ball problem was corrected within a month by chlorination of the column influent at 2 ppm, and by regeneration of approximately 400 ft^3 of carbon from each column. The problem could have been corrected much quicker,had the need existed, by more rapid withdrawal of the affected carbon. Prior to or subsequent to this period, no odors or mud balls have ever been detected although on several other occasions turbidity going on to the carbon had ranged above 1.5 SJU; however, the flow was always maintained above 500 gpm.

As mentioned earlier, the flow can be reversed to down flow configuration. When the headloss across the carbon column reached 12 ft of water,the flow was reversed for about 1/2 hour. This action dropped the headloss to its normal value of 5 ft. The frequency of down flushing the columns varied with the quality of water going onto the carbon. During normal conditions (0.1 - 0.5 SJU carbon column influent) the interval of

FIGURE 69

CARBON DE-FINING TANK


REGENERATED CARBON
FROM QUENCH TANK
EXIT FOR SCREEN
BACKWASH WATER
SCREEN
BACKWASH WATER
TOP WAFER VALVE
WELL SCREEN
DRAIN
VALVE
PRESSURIZING AND
WASH WATER VALVE
BOTTOM WAFER VALVE
TRANSFER WATER
REGENERATED CARBON
BACK TO CARBON
COLUMN

down flushing ranged between 2-4 weeks. As the turbidity increased to 2.5 SJU, the frequency of down flushing increased to once a shift.

During the study, approximately 200 ft^3 of spent carbon was withdrawn from each column for regeneration at 4 to 8 week intervals. The regeneration periods were initiated when the percent removal of COD dropped to about 40% or when the final effluent began to approach its export limits for COD and MBAS due to poor treatment by the secondary system or changes in plant influent waste characteristics. During periods when the secondary system was performing exceptionally well (carbon column influent COD values 10-14 mg/l), COD removal efficiencies of less than 40% were permitted. This practice appeared to give satisfactory usage of the carbon and it produced excellent effluent results. However, this practice, as demonstrated by later data, resulted in variable loadings.

Carbon Regenerating Operating Practices. At the beginning of a regeneration period the carbon furnace was fired. As furnace temperature was being raised to regeneration levals over a period of 24-48 hours, a slug of carbon (about 200 ft^3) was withdrawn from the bottom of the first column to be regenerated and transferred to one of the two dewatering bins. When the regeneration of the first slug was nearing completion, a slug (200 ft^3) was withdrawn from the next column and transferred to the remaining empty dewatering bin and so on, through all six columns until the regeneration of a slug from each was completed, usually in 9 to 11 days. The furnace was then slowly cooled down and shut off until the next regeneration period.

To withdraw spent carbon from the bottom of a column, the flow in the normal upflow direction was increased to more than 1000 gpm with the effluent piped to waste, the peripheral water jets turned on, and the pressure raised from the 5 psig to 20 psig. After the transfer water was established, spent carbon was introduced into the transfer line. Once the transfer was complete, the column was operated upflow-to-waste for 30 minutes at normal pressures and 1200 gpm to remove additional carbon fines. The column then was restored to service until the defined regenerated carbon was ready to be returned hydraulically to the top of the carbon column from which it had previously been withdrawn.

Time periods between 1 and 48 hours were equally effective in dewatering the spent carbon prior to regeneration. This confirms earlier work which indicated that dewatering times between 1 and 26 hours produced moisture contents of 40.3 to 43.7 percent on a wet weight basis.

Regenerated carbon leaving the furnace was continuously quenched and was pumped by an air diaphram pump to one of two defining tanks similar to the one in Figure 69. After approximately 60 to 80 ft^3 of regenerated carbon had been pumped into the tank, the feed was switched to the second vessel. The carbon in the first tank was defined by washing, then the defining tank was pressurized and the contents transferred by water slurry back to column from which the carbon was originally withdrawn. Carbon defining required approximately 1 hour with backwashing of the tank effluent screens about every 15 minutes.

By judicious use of the two dewatering bins and defining tanks and by taking into account the furnace detention time (25-30 minutes), the same carbon was kept in a given column throughout the grant period. At the same time, the furnace was kept full of carbon all through a regeneration period.

The carbon regeneration system is shown in Figure 67 and Figure 68. The spent carbon slurry bin (Figure 68) was not used during the grant period in order to prevent mixing of spent carbon from different columns. Its use would, however, have eliminated many of the carbon regeneration maintenance and makeup carbon costs associated with furnace start-up and shut-down by permitting longer regeneration periods at less than design plant flows. The makeup carbon bin was basically used to receive virgin makeup carbon. After defining the virgin carbon was transferred to carbon column No. 7 for storage. Once again, the makeup carbon slurry bin would serve a very important function in a continuous regeneration scheme.

The amount of steam fed during the grant period was not measured directly but was approximately one pound of steam per pound of dry carbon. Early grant work showed that this markedly improved carbon regeneration.

Excess oxygen in the burners was held to 3% at the number 4 hearth and 1% at the number 6 hearth. In the early periods of the grant, the excess oxygen was checked periodically. However, as the percent carbon losses began to increase above 6% with second and third cycle carbon regeneration, the O_2 concentration was checked before each regeneration to insure that excess oxygen was not contributing to the higher losses.

The number 6 hearth was also kept under slightly positive pressure conditions (+0.05 inches H_2O-gage pressure) to further limit the possibility of excess oxygen entering the furnace.

The regeneration furnace was designed such that the hearth temperature, furnace feed rate, rabble arm speed and steam could be used to control the carbon regeneration. The rabble arm speed of 0.92 rpm was held constant throughout the grant, and steam at about one pound per pound of carbon was used for each regeneration. Of the two remaining parameters, feed rate and temperature, the feed rate was found to be the most responsive control.

The apparent density of the carbon was used for plant control of the carbon regeneration. It was found that hourly apparent density measurements were necessary to keep the regenerated carbon apparent density between 0.48 and 0.49 gms/ml, the desired range for the 8 X 30 mesh virgin carbon. Hourly checks were necessary because of the different regeneration cycles from column to column and because the carbon within an individual slug from a column had been loaded differently due to position within the column prior to regeneration. It is interesting to note that as the regeneration cycles of the carbon increased, the differences between columns and carbon within a slug decreased to the point that at the time of this report very little change in either temperature or feed rate was being made from the beginning to the end of a batch regeneration period.

Carbon Column Maintenance. Aside from some very early corrosion problems, the carbon columns have required very little maintenance.

The original two carbon columns (1965), coated with 8 mils of coal tar epoxy, were inspected in January 1968, after about 30 months of operation and were found to be severely pitted by electrolytic corrosion. Pits to 3/16 inch deep occurred over wide spread areas of the upper half of each column. The columns interiors were sand blasted to grey metal and an improved coal tar epoxy material was applied to each column. For experimental purposes, 28 mils of the new material was applied to carbon column No. 1 and 18 mils to carbon column No. 2. The columns, including five of the six new columns placed into service in March 1968 (Nos. 3-8), were reinspected between October and December 1970 after 32 months of continuous operation. Carbon columns No. 1 through No. 6 showed no signs of corrosion and No. 8 column showed only very slight signs. No. 7 column which was being used to store virgin carbon was not inspected.

At the time of the recoating in January 1968, it was felt that either the dielectric strength of the original 8 mil coal tar epoxy was not sufficient or that pin holes existed after its factory application. The fact that the six new columns, installed in late 1967, were coated to the same 1965 specifications and that these later columns have been almost completely free of corrosion suggests that the original 8 mil coating (1965) was not applied correctly. The experience to date also suggests the heavier recoatings were adequate.

Carbon Regeneration Maintenance. The carbon regeneration system, like two of the separation beds, has been used since 1965. References describe its use from 1965 to 1968, hence this discussion will carry the maintenance and modification experience forward from January 1968 to January 1971.

The unlined iron pipe carbon slurry transfer lines, some dating back to 1965, have not been replaced to date. One 90° ell on the suction side of a diaphram pump was replaced due to electrolytic corrosion. The maintenance of the stack gas scrubber due to increasing carbon fines is discussed later in the section on carbon losses. The carbon defining tank screens have also been affected by the fines. Before each batch regeneration period, the tanks are entered and the Johnson well screens are wire-brushed. After approximately every third period, since July 1969, the screens have been removed and acid cleaned (10% HCl) in order to completely remove the carbon fines.

The furnace, aside from replacement of the gas burner zero governors in 1970, and the draft fan electric motor in 1969, has had no major maintenance costs. However, because of the batch regeneration periods resulting from grant studies and plant flows higher than normal, maintenance labor costs have been associated with each furnace start-up.

Since 1968 several modifications have been made to the carbon regeneration system. In July 1968 the Neva-Clog screens in the defining tanks were replaced with Johnson well screens. The original screens plugged very rapidly and eventually ruptured.

In July 1969, copper tubing was installed between hearths of the carbon regeneration furnace and the atmospheric vent on each of the gas burner zero governors. This simple but important change has eliminated burner flame-outs. Prior to this modification, the burners were hard to light during start-up and flamed-out numerous times during a given carbon regeneration. Fluctuating pressure within the furnace was suspected to have caused the flame-outs.

Sampling and Data Collection. Automatic twenty-four hour composite samplers, paced on the flow through the separation beds and carbon columns, provide daily composites of the separation bed effluent and the carbon column effluent. During the data collection period, the six columns on line were individually sampled by manually compositing twenty-four hour samples of each column's effluent at a two hour interval.

The laboratory analysis schedule for the above samples in relation to frequency and parameters analyzed, is described in another section of this report. The parameters analyzed across the carbon adsorption process were COD, BOD, MBAS, and color. The parameters, with the flow data, provided several different evaluations of the carbon process, which are described later in the carbon section.

Daily, during the data collection period, the individual carbon column effluent's flow rate and headloss were recorded at two hour intervals. Also at the same time the flow totalizer reading for all water passing through the separation beds, including filter-to-waste flows, was recorded.

For the first 15 months of the data collection period, March 31, 1968 to June 30, 1969, on an individual column basis, the daily total flow, cumulative flow, flow passed since the previous regeneration, average hydraulic loading, and the loading and removal efficiencies of MBAS and COD were computed manually. From July 1, 1969 to November 30, 1970, more extensive data collection and analysis were available.

During the grant period, twenty batch regenerations were necessary to insure the water reclamation plant's effluent met the stringent export standards. In the first batch regeneration, carbon was withdrawn from only three of six columns, and only four in the second regeneration. In the last eighteen regenerations, carbon was withdrawn uniformly from each of the six columns.

Each time spent carbon was withdrawn from a column, an approximate one liter sample of spent carbon was composited during the transfer. The composited sample was indentified and placed in a drying oven at 300°F. After the spent transfer was completed, the surface of the carbon in the dewatering bin was leveled, and the freeboard depth was measured to compute the approximate volume of the transfer.

After the carbon had passed through the furnace, an operational sample before quenching was taken hourly for apparent density determination. A fixed portion of each operational sample was composited throughout each individual column's batch regeneration. This composite was also placed in the 300°F drying oven. After quenching and defining, the freeboard in the defining tank was measured, and the volume computed. The regenerated carbon was then transferred back to the respective column from which the spent was withdrawn.

At periodic intervals during the grant period the freeboard in each carbon column was measured before spent withdrawal and after the regenerated carbon was added. A log of carbon transfer volumes and column freeboard depths was also kept, which was used to provide a history of each column. The history provided an accurate account of the volume of carbon in each column at a given time, when a regeneration had taken place, and the volumes of spent withdrawn and regenerated added, and if any makeup carbon had been added. With these facts, the regeneration cycle and regeneration losses of each individual column's carbon could be determined.

To further evaluate carbon losses in regeneration and transport, sieve analyses were performed on sixty composite samples of spent and regenerated carbon from five batch regenerations of all six carbon columns. Twelve additional sieve analyses were performed on carbon column six regenerated composites around the quenching and defining systems.

During the actual regeneration period, a log was kept, giving the dewatering bin from which carbon was being extracted, the numerical setting on the variable speed carbon auger, the hourly apparent densities and hearth temperatures, steam addition, and every four hours, the natural gas meter reading. A strip chart also provided continuous hearth temperature readout. From this data the furnace feed rate, gas consumption, and average hearth temperatures could be determined.

After drying at 300°F for at least three hours, the spent and regenerated composites were individually split a number of times to obtain a representative sample. The sample was pulverized in a ball mixer-mill, and iodine number and percent ash analyses were made. Also an average apparent density was determined on each column's spent and regenerated composite sample. From this data could be determined the efficiency of a particular regeneration.

Average Results of Carbon Adsorption and Regeneration. During the thirty-two month data collection period of 1 April 1968 to 1 December 1970, the activated carbon adsorption columns treated approximately 3600 million gallons of separation bed effluent. The monthly average for the period was 113 MG, with the lowest monthly flow being 80 MG and the highest 154 MG. The average detention or superficial contact time was 19.2 minutes, which provided an average loading rate of 4.7 gal/min/ft^2.

The average COD concentration in the separation bed effluent was 20.3 mg/l, which resulted in approximately 612,000 pounds of COD being applied to the carbon during the period. The average COD concentration in the carbon column effluent was 10.0 mg/l. Approximately 311,000 pounds of COD were removed by the activated carbon, which resulted in a removal efficiency of 50.8%.

The average MBAS concentration in the separation bed effluent was approximately 0.6 mg/l, which resulted in 18,800 pounds of MBAS being applied to the carbon. The average carbon column effluent MBAS concentration was slightly more than 0.1 mg/l, which provided a removal efficiency of 77%.

The average BOD concentration in the Separation Bed effluent was about 4 mg/l, and the carbon column effluent BOD ranged from 1-3 mg/l. The chlorinated carbon column effluent BOD concentration averaged 1.2 mg/l over the period. Since reliability and accuracy of the BOD determination in these ranges is questionable, no further correlations for BOD were made in the evaluation of the carbon adsorption system.

The average color concentration in the separation bed effluent was slightly over 11 color units with the cobalt standard, and the average carbon column effluent color value was between 5 and 6 color units. The color removal efficiency across the carbon averaged slightly below 50% for the grant period.

Between October 1968 and January 1971, the carbon column flow was 3,341 MG and 23,050 ft^3 or 691,000 pounds of activated carbon were regenerated, providing a carbon dosage rate of about 207 pounds of regenerated carbon per million gallons of carbon column flow. For the same period, an average of 0.8 pounds of COD were applied per pound of regenerated carbon, and 0.38 pounds of COD were removed per pound of carbon. An average of 0.027 pounds of MBAS were applied per pound of regenerated carbon, and 0.021 pounds of MBAS were removed per pound of carbon.

The average furnace feed rate for the batch regeneration periods was 176 pounds per hour, or about 6 cubic feet per hour. Fuel requirements per pound of carbon averaged 2900 BTU at 860 BTU per cubic foot of natural gas at 18-20 psia. Numbers four and six furnace hearth temperatures averaged 1650 and 1670°F, respectively. Carbon losses in the furnace and in transport to and from the furnace averaged 8% during the period.

The virgin carbon, from the 1965 and 1968 purchases, had an average iodine number of 935, an apparent density of .485 gms/ml, and an ash content of 5.0 percent. The spent carbon before regeneration had an average iodine number of 583, an apparent density of .571 gms/ml, and an ash content of 6.4 percent. The regenerated carbon had an average iodine number of 802, an apparent density of 0.487 gms/ml, and ash content of 6.8 percent.

The oldest carbon at Tahoe had been regenerated four times and the newest carbon two times. In the batch regeneration used at Tahoe, it took approximately one year for an entire column to pass through one regeneration cycle.

Effect of Carbon Regeneration Cycles on Organics Removal. As a result of the batch regeneration procedures used at South Lake Tahoe, two different carbon column historys are required to evaluate the efficiency of the activated carbon to remove organics over several regeneration cycles. Since it takes approximately an average of one year for one entire carbon column to pass through one regeneration cycle, carbon purchased in 1965 and 1968 was used for this evaluation. Both carbons are the same brand and type, Calgon Filtrasorb 300, 8 X 30 mesh. The carbon in Carbon Column Six (CC-6) is from the 1965 purchase, and the carbon in CC-5 is from the 1968 purchase. When the grant's extensive data collection program was initiated on March 31, 1968, CC-6 was in its second regeneration cycle, and CC-5 was virgin. At the end of the data collection program, CC-6 was in its fifth cycle and CC-5 was in its third cycle. Since the regeneration cycles of CC-5 and CC-6 are not identical chronologically, only the portions of each cycle that are identical in relation to loading period are used. This method was used to eliminate the problems of variable flow and waste strengths encountered in plant scale research.

The organic removal efficiencies for portions of four regeneration cycles are shown in Tables 24 and 25 . Since the regeneration of approximately 50,000 lbs of carbon is required before one regeneration cycle of a column is complete, the comparison of first cycle CC-5 and third cycle CC-6 (Table 24) represents 80% of the total regeneration cycle, and the comparison of second cycle CC-5 and fourth cycle CC-6 (Table 25) represents 75% of the total cycle.

In Table 24, the comparison period of first cycle CC-5 and third cycle CC-6, CC-5 was loaded slightly higher and had a slightly lower

TABLE 24

A Comparison of COD and MBAS Removal Efficiency Between First Cycle CC-5 and Third Cycle CC-6

Carbon Column	CC-5	CC-6
Regeneration Period	11/15/68 to 10/5/69	
Regeneration Cycle	First	Third
Total Flow in Period	202.2	189.3
Total Pounds of Carbon Regenerated in Period	40960	41100
Carbon Dosage $\frac{\text{lbs reg.}}{\text{MG}}$	202	217
Chemical Oxygen Demand		
Influent mg/l	18.2	18.2
Effluent mg/l	9.5	8.0
Percent Removal	47.8	55.0
lbs In	30720	28693
lbs Removed	14695	16084
lbs In/lb Carbon Reg.	.75	.70
lbs Removed/lb Carbon Reg.	.36	.39
Methylene Blue Active Substances		
Influent mg/l	.55	.55
Effluent mg/l	.13	.13
Percent Removal	76.4	76.4
lbs In	927	869
lbs Removed	708	663
lbs In/lb Carbon Reg.	.023	.021
lbs Removed/lb Carbon Reg.	.017	.016

TABLE 25

A Comparison of COD and MBAS Removal Efficiency Between Second Cycle CC-5 and Fourth Cycle CC-6

Carbon Column	CC-5	CC-6
Regeneration Period	1/7/70 to	8/6/70
Regeneration Cycle	Second	Fourth
Total Flow in Period	142.3	140.5
Total Pounds of Carbon Regenerated in Period	37170	37170
Carbon Dosage $\frac{\text{lbs reg.}}{\text{MG}}$	260	264
Chemical Oxygen Demand		
Influent mg/l	22.6	21.7
Effluent mg/l	12.3	12.1
Percent Removal	45.6	44.3
lbs In	26802	25407
lbs Removed	14556	14145
lbs In/lb Carbon Reg.	.72	.68
lbs Removed/lb Carbon Reg.	.39	.38
Methylene Blue Active Substances		
Influent mg/l	1.03	1.03
Effluent mg/l	.32	.25
Percent Removal	68.9	75.7
lbs In	1220	1205
lbs Removed	843	913
lbs In/lb Carbon Reg.	.033	.033
lbs Removed/lb Carbon Reg.	.023	.024

COD removal efficiency, 0.36 lbs COD removal/lb Reg. Carbon as opposed to 0.39 for CC-6, and a lower percent removal, 48% as opposed to 55% for CC-6. MBAS removals are practically identical for the two cycles regardless of flow.

In Table 25, the comparison period of second cycle CC-5 and fourth cycle CC-6, the applied loadings for both COD and MBAS are almost identical, and practically identical removal efficiencies for both parameters were attained.

In summary, from the results shown in Tables 24 and 25, the number of regeneration cycles of the carbon to date did not affect the removal efficiencies. In general, if a wastewater of similar volume and waste strength in terms of COD and MBAS were applied to all four cycles, approximately the same quality effluent would be attained in all four cycles.

Carbon Column Loading Rate Investigation. A controlled loading rate investigation was performed by operating Column #1 at 2 gpm/ft^2, Column #2 at 4 gpm/ft^2, and Column #4 at 6.5 gpm/ft^2 representing contact times of 45, 22.5 and 15 minutes, respectively. The three columns used for this study all contained virgin carbon initially at the same depth. As these columns were identical in size, it was not possible to separate the effects of loading rate and contact time.

As shown in Figure 70 no obvious correlation was found to exist between the loading rate and removal of MBAS. However, Figure 71 does show that removal of COD at the lower rate was substantially better than at either of the higher rates. All three loading ratings show a slight decrease in efficiency at about 40 MG of throughput.

Both capital expenditures, including the initial carbon charge, and the carbon dosage would affect the economies of different loading rates. A direct economic comparison, however, cannot be made since the tests were terminated before each column had reached the same specific adsorption efficiency.

Carbon Loading and Regeneration Over An Extended Period of Time. An extensive amount of data was collected during the grant period to evaluate the efficiency and quality of the twenty batch carbon regenerations. The first portion of this section describes the specific data collected and the results. At the end of the grant period, adsorption isotherms were determined on selected samples from the twenty batch regenerations. The results and discussion of the isotherm evaluations comprise the second portion of this section.

FIGURE 70

MBAS REMOVAL FOR CONTROLLED LOADING RATES

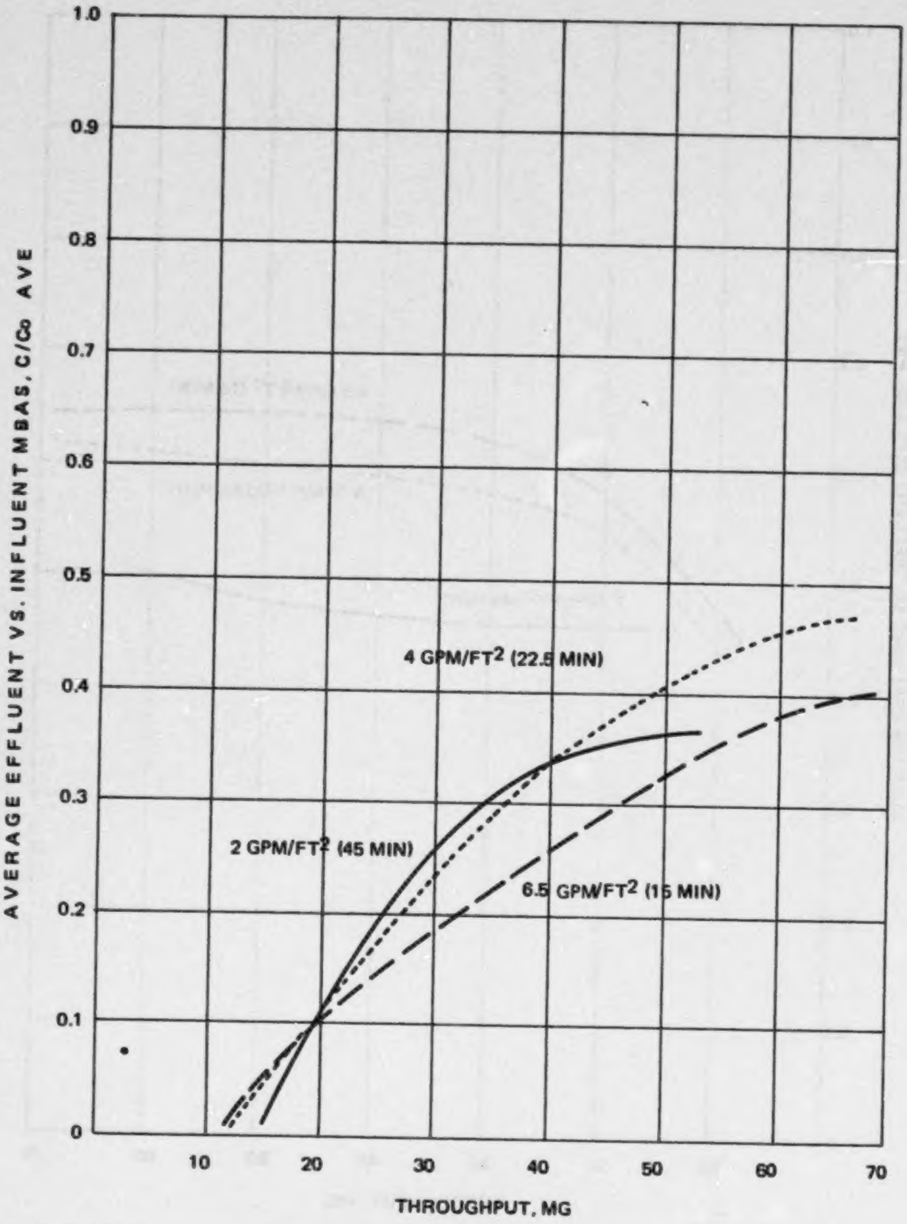
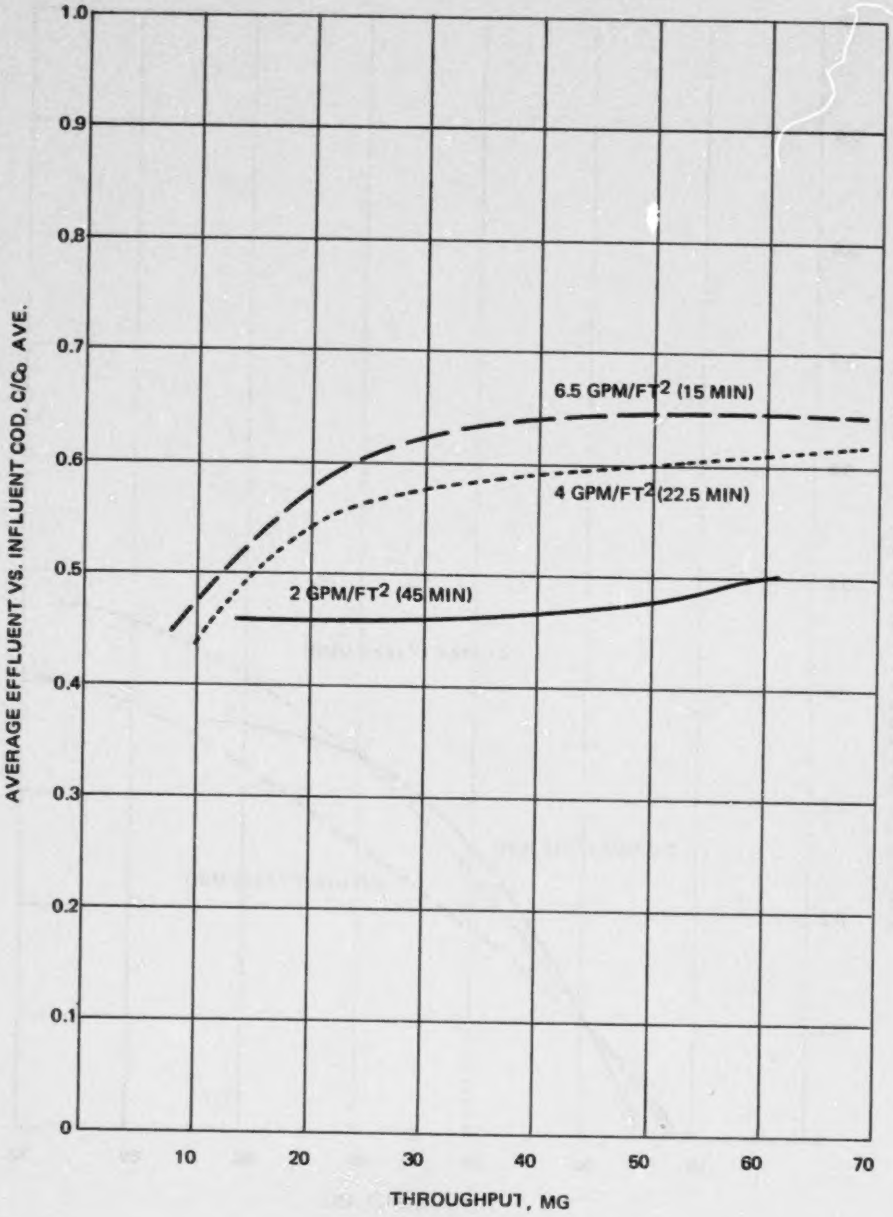


FIGURE 71

COD REMOVAL FOR CONTROLLED LOADING RATES



To demonstrate the ability to regenerate activated carbon over an extended period of time, data was collected on carbon dosage, iodine number, apparent density, ash buildup, as well as Chemical Oxygen Demand (COD) and Methylene Blue Active Substances (MBAS), carbon loadings, and efficiencies. The regeneration parameters of carbon feed rate, fuel requirements and hearth temperatures were also recorded.

The data from each carbon column was combined and averaged for each of the batch regeneration periods. Table 26 presents the average, maximum, and minimum values based on the regeneration period averages for November 1968 through January 1971.

The carbon dosage of 207 lbs/MG (Table 26) is based on the total flow passed through the carbon columns and the total amount of carbon regenerated. Basically, the flow period was from September 1968 to January 1971. The time prior to September 1968 was used for flow rate studies. An average of 90 MG through-put and one batch regeneration period occurred prior to September 1968. The through-put of the carbon columns included more than 1 MGD of plant process recycle water that was not part of plant influent or export flows.

The individual batch regeneration periods, on which Table 26 is based, are shown in Figures 72 and 73 . The average increase in iodine number after carbon regeneration is shown by Figure 74 . Finally, the bar graph in Figure 75 indicates the regeneration cycle of each carbon column at the beginning of a batch regeneration period.

In Figures 72 and 73 the dates represent months during which batch regeneration periods occurred. The iodine numbers are averages for a specific regeneration period. The loadings and efficiencies for a particular date are averages of what occurred between the beginning of the previous regeneration period and the beginning of regeneration period represented by the date in question.

Several observations may be drawn from both Figures 72 and 73 . In Figure 72 , the COD influent concentration and pounds applied to carbon increased significantly from July 1969 to May or June 1970. At the same time, the spent and regenerated iodine numbers began decreasing. Between October 1969 and April 1970 no effort was made to compensate for the increasing COD loadings by increasing the carbon dosage. Hence, between October and April, the carbon efficiency also began to fall. In May 1970, much higher carbon dosages were initiated. At the same time, the influent COD began to drop. The net effect of increasing carbon dosages during declining loadings was to bring about an improvement in the iodine number and to some extent, COD efficiency. Toward the end of

TABLE 26
Average Carbon Efficiency Per Regeneration Period
November 1968 Through January 1971

Parameter	Average	Maximum	Minimum
Carbon Dosage (lbs.Reg./MG Treated)(2)	207	418	111
Iodine Number(1)			
Spent Carbon	583	633	497
Regenerated Carbon	802	852	743
Apparent Density (gm/ml)(1)			
Spent Carbon	0.571	0.618	0.544
Regenerated Carbon	0.487	0.491	0.478
Percent Ash(1)			
Spent Carbon	6.4	7.0	5.8
Regenerated Carbon	6.8	7.2	5.8
Chemical Oxygen Demand			
Percent Removal	49.9	63.3	30.1
lbs. COD Applied	28,250	54,970	15,680
lbs. COD Applied per MG	162	254	105
lbs. COD Removed per MG	81	149	32
lbs. COD Applied per lb. Carbon Regenerated(2)	0.78	1.56	0.52
lbs. COD Removed per lb. Carbon Regenerated(2)	0.39	0.71	0.16
Methylene Blue Active Substances (MBAS)			
Percent Removal	77.0	93.0	58.0
lbs. MBAS Applied	995	1675	457
lbs. MBAS Applied per MG	5.7	10.7	2.6
lbs. MBAS Removed per MG	4.4	8.2	1.6
lbs. MBAS Applied per lb. Carbon Regenerated(2)	0.027	0.045	0.012
lbs. MBAS Removed per lb. Carbon Regenerated(2)	0.021	0.039	0.007

(1) November 1968 through November 1970

(2) Based on ft^3 of carbon fed to furnace at 30 lbs/ft^3

FIGURE 72

A COMPARISON OF COD EFFICIENCY, IODINE NO. AND CARBON DOSAGE BY CARBON REGENERATION PERIODS

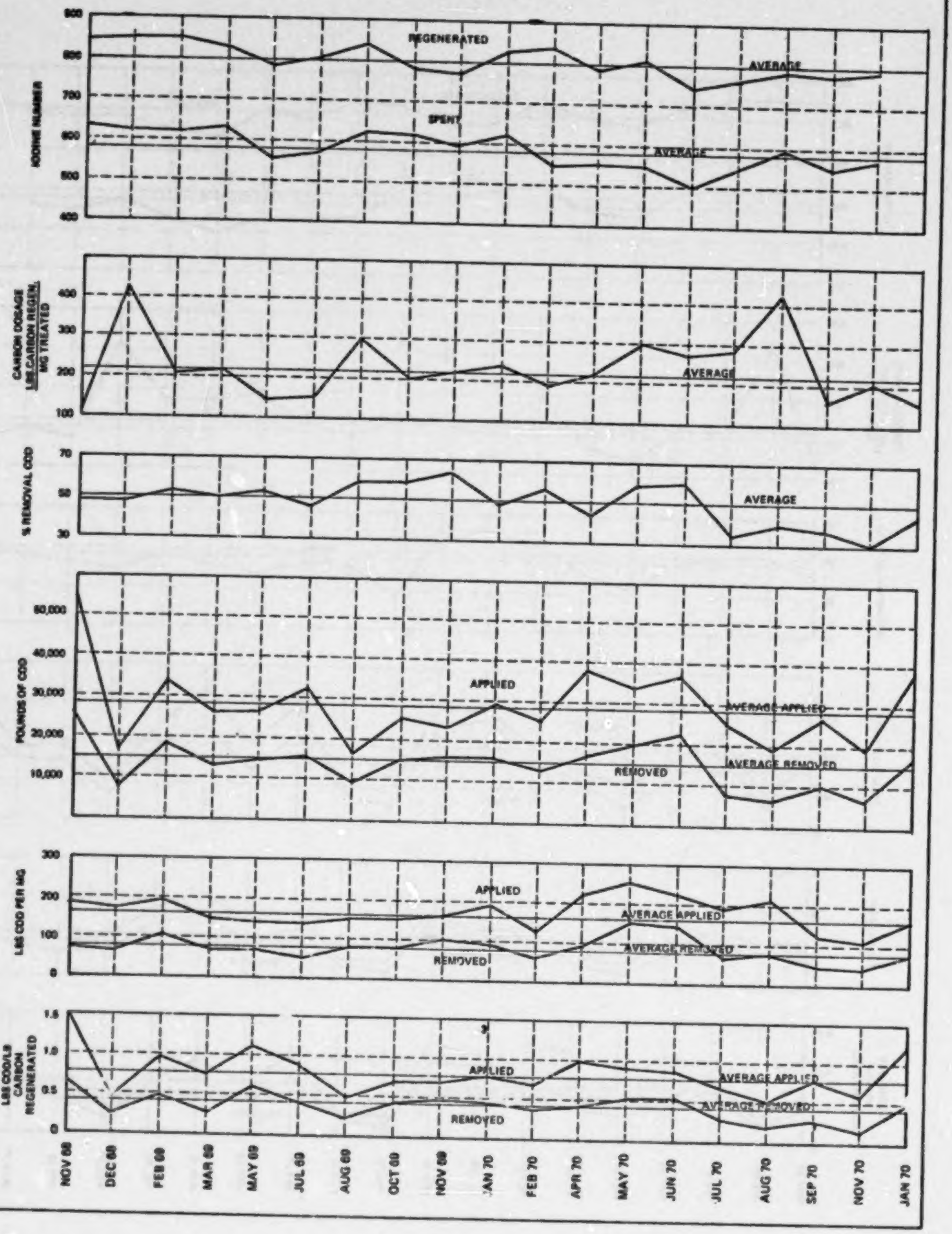


FIGURE 73

A COMPARISON OF MBAS EFFICIENCY, IODINE NO.
AND CARBON DOSAGE BY CARBON
REGENERATION PERIODS

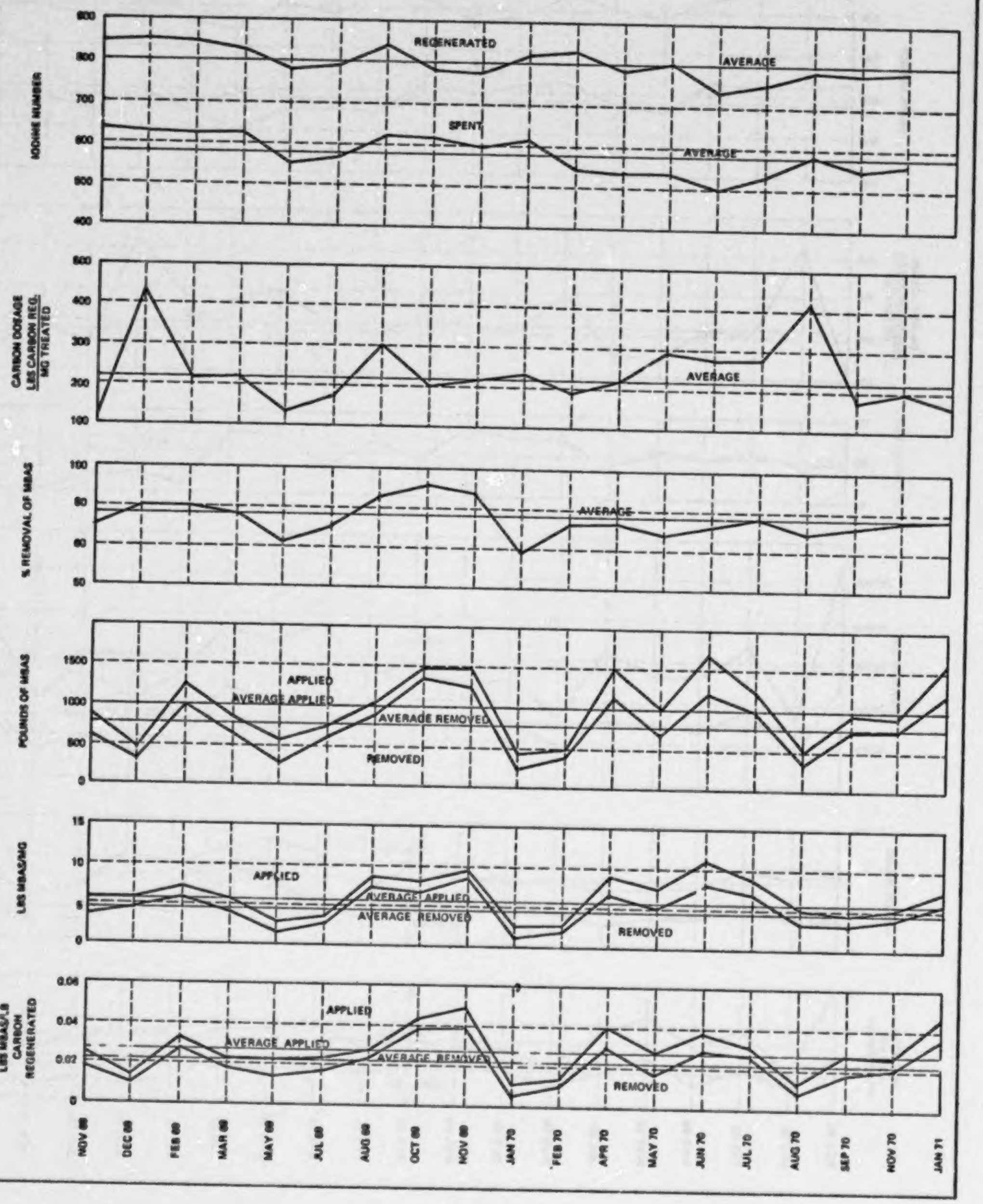


FIGURE 74

INCREASE IN SPENT CARBON IODINE NUMBER BY THERMAL REACTIVATION

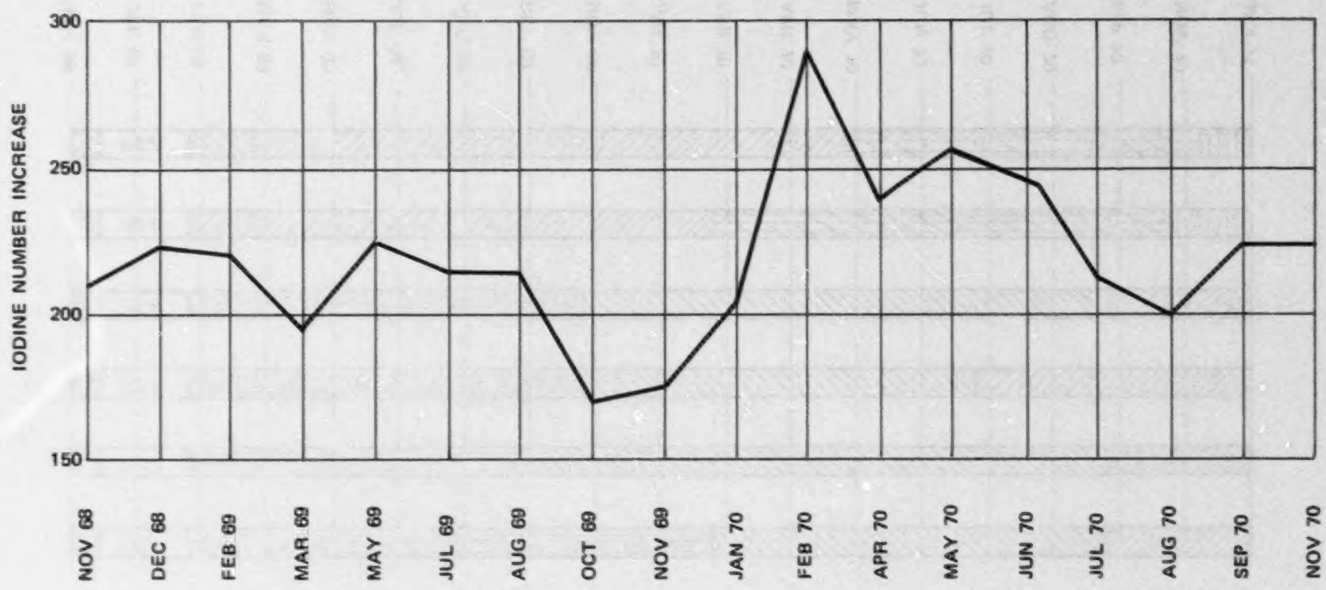
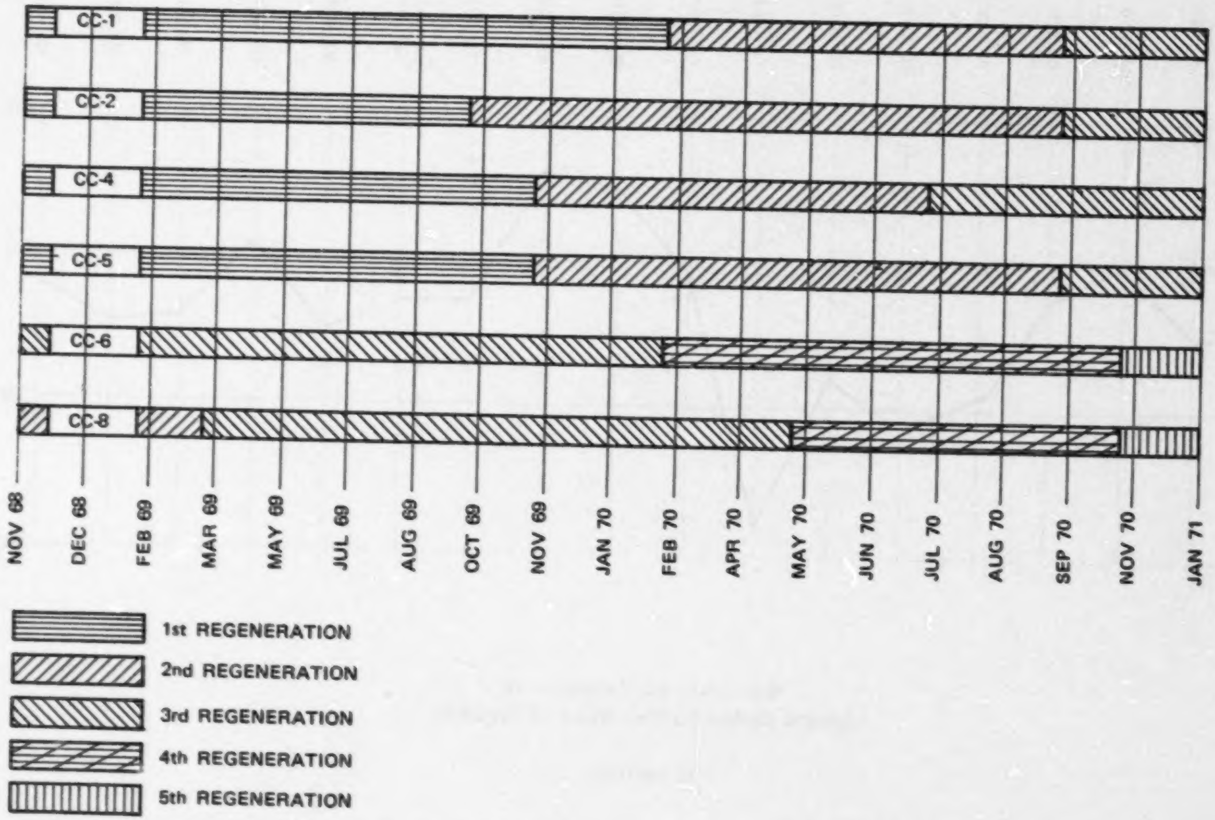


FIGURE 75

CARBON REGENERATION CYCLES



the grant period, carbon efficiency for COD seemed to be effected more by applied COD loadings than in earlier periods. Hence, the recovery in efficiency was not as pronounced.

The ability of the carbon to remove ABS and alkyl sulfates is shown in Figure 73. Unlike COD, carbon efficiency for MBAS between November 1968 and February 1970 was very dependent on the applied MBAS loading. After February 1970 the applied loading appeared to have very little effect on the carbon efficiency. From Figure 73, one can see that this change occurred shortly after the transition of 67% of the carbon to the second cycle of regeneration and 33% to the fourth cycle. Further, the MBAS efficiency was not effected by the increased carbon dosage between May and August 1970.

Under variable loading conditions and carbon regeneration cycles, the regenerated iodine number seems to be leveling off at near 800. However, both Figures 72 and 73 show that the regenerated iodine number is dependent on the spent iodine number, that is the change in iodine number with regeneration is fairly constant.

Table 27 presents the average carbon furnace conditions from the regeneration period in November 1968 through that in November 1970. The higher feed rate and lower fuel and temperature requirements occurred during the early stages of the grant. Conversely, it has taken higher temperatures at lower feed rates to regenerate the carbon toward the end of the grant.

A portion of the evaluation of the ability to regenerate activated carbon over an extended period of time consisted of determining adsorption isotherms for four regeneration cycles and the virgin carbon. Chemical oxygen demand and methylene blue active substance (detergents) adsorption isotherms were determined on the virgin carbon, three batch regeneration samples from carbon column five (CC-5), which were chronologically three total column regeneration cycles apart, and on one batch regeneration sample from the fourth total regeneration of CC-8. The CC-8 sample was chosen because it was chronologically as far into its fourth total column regeneration cycle as the third cycle sample of CC-5 was into the third total regeneration. Also the CC-8 sample was of particular interest because it had a very low spent and regenerated Iodine Number compared to the average during the grant period.

The adsorption isotherm procedure used is described in Section XI. Prior to determining the isotherms for the above samples, the length of the shaking period or contact time required to reach equilibrium was

TABLE 27

Average Carbon Furnace Parameters
Per Regeneration Period
November 1968 Through November 1970

Parameter	Average	Maximum	Minimum
Furnace Feed Rate(1) (lbs/hr)	176	266	139
Fuel Requirements(2) (BTU/lb carbon)	2900	4510	1820
Hearth Temperatures ° F			
No. 4 Hearth	1650	1460	1720
No. 6 Hearth	1670	1560	1740

(1) Amount fed to furnace per hr at 30 lbs/ft^3

(2) Natural gas requirements per lb. of carbon fed to furnace at 860 BTU/ft^3 and 18 - 20 psia

investigated by contacting equal volumes of separation bed effluent (500 mls) with equal volumes of carbon CC-5, second cycle, spent, (25 mg) for 30 minutes, 1, 2, and 3 hours. The results indicated that both COD and MBAS reached equilibrium within 30 minutes to 60 minutes. A two hour shaking period was chosen, and used for all the remaining isotherm determinations.

Before the isotherms and their conclusions in reference to extended regeneration ability are revealed, a short discussion of the full scale carbon column operation and isotherm theory is necessary.

First, because of the stringent export requirements the water reclamation plant effluent must meet, the carbon columns cannot be operated until their theoretical ultimate capacity or saturation is reached. Consequently, the ultimate capacities attained in the laboratory with the isotherms are never reached in full scale operation.

Second, as is the accepted procedure, a ball mixer was used to pulverize the carbon samples for the isotherm determinations, to eliminate the variability of adsorption in accordance with the diameter of carbon granules. Since the adsorption rate determining step is the migration of the adsorbate from the surface of the carbon granule to the adsorption site within, the larger 8 X 30 mesh granules require a longer adsorption time and again, the theoretical ultimate capacity attained in the laboratory can never be reached in full scale operation.

Third, the daily variation in the COD and MBAS strength of the separation bed effluent will alter the theoretical ultimate capacity attained in the laboratory, since the adsorption driving force is higher for higher COD and MBAS concentrations applied to the carbon.

The COD adsorption isotherms attained for the above described samples are shown in Figures 76 through 78 . In Figure 76, the COD isotherms attained with the virgin and three regenerated cycles of CC-5 and fourth cycle of CC-8 are shown with the symbol "┐", indicating the ultimate capacity for each carbon. The variance of the COD concentration in the separation bed effluent results in erroneous numerical results for the ultimate capacity, since the 12-68 CC-5 regeneration has a capacity greater than the virgin ultimate capacity which is highly unlikely. However, the slopes and position of the respective isotherms provide a more reasonable basis for comparison. The isotherms indicate that for any COD in the separation bed effluent from 20-100 mg/l, the ultimate capacities for the regenerated samples would fail below the ultimate capacity for the virgin sample. During the isotherm evaluations, the COD concentration

VIRGIN AND THREE REGENERATION CYCLES
OF CC-5, DECEMBER 1968, JANUARY 1970, AND NOVEMBER 1970,
AND FOURTH CYCLE OF CC-8, JULY 1970

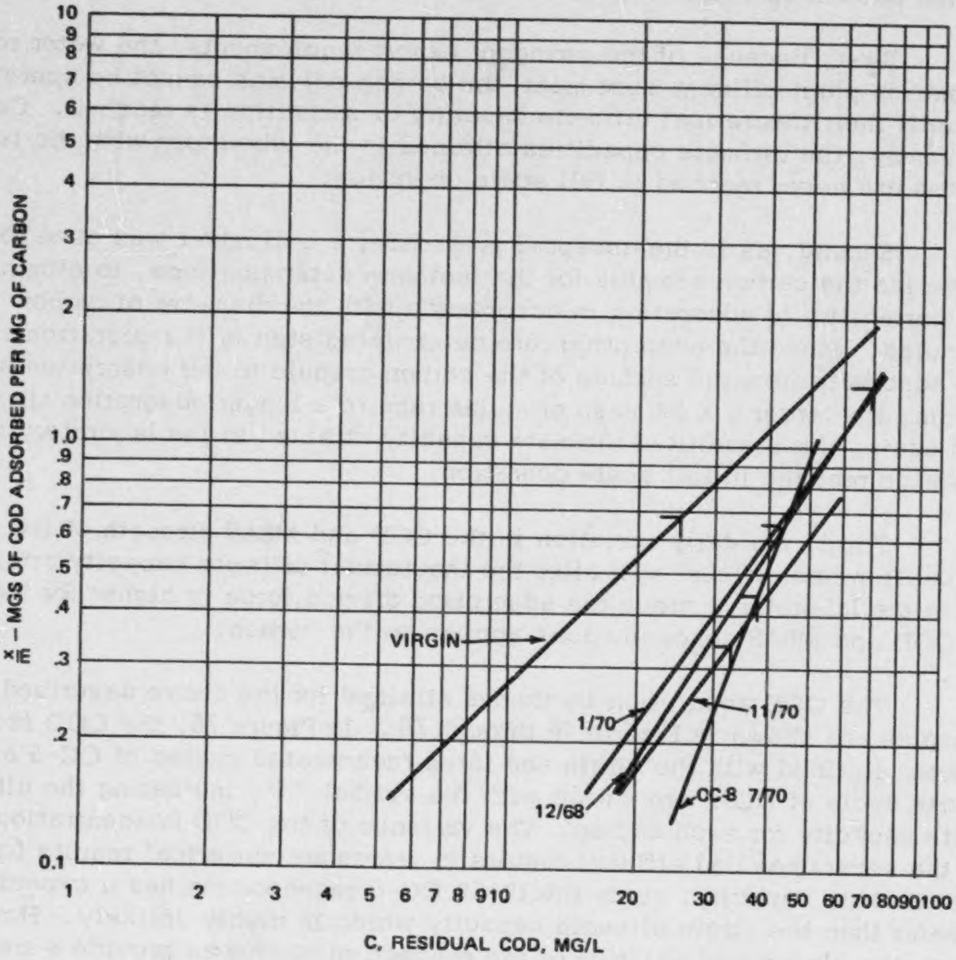
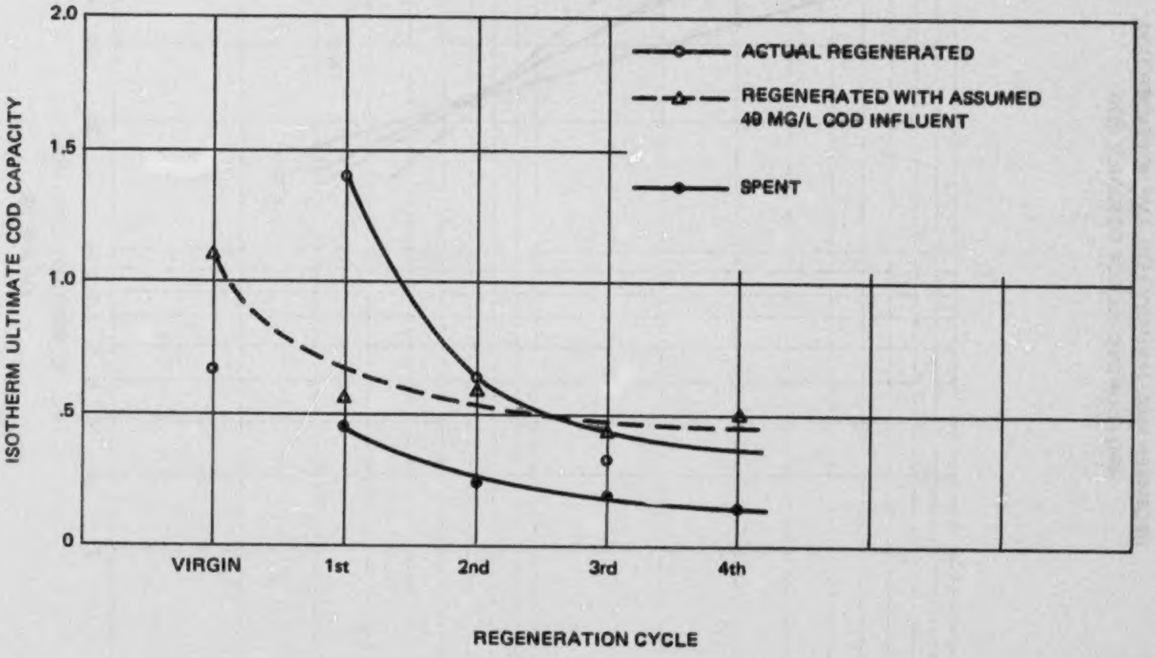


FIGURE 76

ISOTHERMS FOR VIRGIN AND REGENERATED CARBON

FIGURE 77

ISOTHERM SPENT AND REGENERATED
ULTIMATE COD CAPACITY
VS
FOUR REGENERATION CYCLES



THREE SPENT CYCLES OF CC-5
DECEMBER 1968, JANUARY 1970, AND NOVEMBER 1970,
AND FOURTH CYCLE OF CC-8, JULY 1970

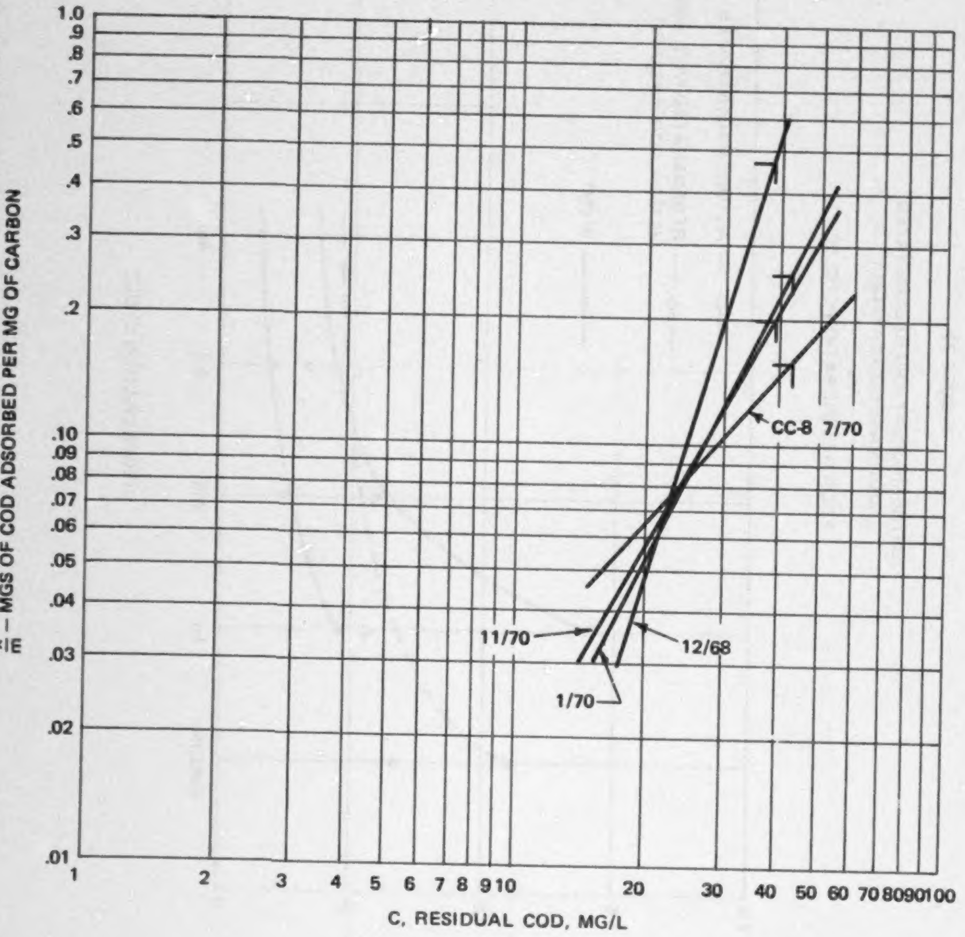


FIGURE 78

ISOTHERMS FOR REGENERATED CARBON

in the separation bed effluent was averaging around 40 mg/l. If the ultimate capacities at 40 mg/l influent are plotted for the virgin, three samples of CC-5, and the fourth cycle of CC-8 from Figure 76 , the resulting curve (Figure 77)of virgin and regenerated samples is derived. The trend indicates that the ultimate capacities in terms of COD decrease sharply during the first regeneration and then appear to level off with only slightly decreasing values. If the actual ultimate capacities obtained from Figure 76 are plotted on the same Figure 77 , the same decreasing and then leveling off trend results; but as indicated above, the virgin ultimate capacity does not follow the trend, because of its low COD influent concentration.

The adsorption isotherms for the three spent cycles of CC-5 and the fourth spent cycle of CC-8 are shown in Figure 78. The separation bed effluent COD concentrations for these evaluations were quite uniform, ranging from 38-43 mg/l, providing an excellent comparison of the four spent cycles. If the ultimate capacities derived from the isotherms of the spent cycles are plotted against regeneration cycles as before, the resulting curve for the spent samples is shown in Figure 77. The curve indicates a similar downward and leveling off trend for the ultimate capacities as the regenerated samples indicated.

The results of the four loading cycles of spent and regenerated samples indicate that, for COD adsorption capacity, the capacity of virgin carbon was not achieved by reactivation of the first cycle spent carbon. At the same time, very little additional capacity was lost by continued reaction of the carbon through the second, third or fourth loading cycles.

To further investigate the trends indicated by the isotherms, iodine numbers were determined on the identical samples of the first through third regeneration cycles of CC-5, and the fourth cycle of CC-8. Table 28 shows the decrease in iodine number due to organic loading, the increase in iodine number due to thermal reactivation, and the net change in iodine number for each regeneration. After the first cycle regeneration, there was a net decrease in iodine number of 118, but the second through fourth cycles indicated much smaller net decreases, which corresponds well with the COD ultimate capacity trends shown in Figure 77.

Attempts were also made to correlate the actual pounds of COD applied and removed, and carbon dosage during a regeneration cycle with theoretical ultimate capacities attained with adsorption isotherms. However, correlations between actual full scale column loadings and the laboratory results were unsuccessful.

TABLE 28

ORGANIC LOADING AND REACTIVATION EFFECT ON IODINE NUMBER

DATE COLUMN CYCLE	12/68 CC-5 First	1/70 CC-5 Second	11/70 CC-5 Third	7/70 CC-8 Fourth
Virgin or Regenerated	972	854	805	794
Spent	678	568	588	530
Loading Decrease	-294	-286	-217	-264
Regenerated	854	805	794	758
Spent	678	568	588	530
Reactivation Increase	+176	+237	+206	+228
Loading Decrease	-294	-286	-217	-264
Reactivation Increase	+176	+237	+206	+228
Net Change	-118	- 49	- 11	- 36

Since organic loading and carbon dosage apparently did not effect the considerable loss of COD adsorption capacity during the first cycle regeneration, data was compiled on furnace operating conditions during each of the batch regeneration periods from which the isotherm samples were obtained.

The resulting information is listed in Table 29. There is considerable difference in all operating conditions between the first regeneration period and the second through the fourth. In comparison, the furnace feed rate is reduced to one-half, while the average hearth temperature required for regeneration is about $50^{\circ}F$ higher. The net result for the second through fourth regeneration periods is that it takes longer to accomplish regeneration, and with the higher hearth temperatures, a considerable increase in gas consumption results. In contrast, Figure 77 shows that at 40 mg/l, regeneration of the first cycle, produced the lowest COD adsorption reactivation efficiency, and that regeneration of the later cycles produced more efficient results in terms of COD adsorption capacity.

As was described earlier, adsorption isotherms for MBAS were also determined on the same samples at the same time as the COD isotherms. The results of the MBAS isotherms for virgin and the four spent and regenerated cycles of CC-5 and CC-8 are shown in Figures 79 through 81. The MBAS isotherms for the virgin and samples from the first three regeneration cycles of CC-5 and a sample from the fourth cycle of CC-8 are shown in Figure 79. It is readily apparent the ultimate capacities for the four regeneration cycles approach very closely to the ultimate capacity of the virgin sample. This is graphically shown in Figure 80, in which MBAS ultimate capacity is plotted against regeneration cycle. The straight horizontal line indicates the carbon was always reactivated back to near the ultimate adsorption capacity of the virgin carbon for MBAS regardless of regeneration cycle.

The MBAS isotherms for the first three spent cycles of CC-5 and the fourth spent cycle of CC-8 are shown in Figure 81. The results indicate the ultimate capacity of the spent samples or their degree of being spent were approximately the same. Again, if the MBAS ultimate capacities for the spent sample are plotted against regeneration cycle as in Figure 80, a curve is obtained which is approximately one-half the magnitude of the line for the regenerated samples. Therefore, in terms of MBAS removals, approximately one-half of the carbon's adsorption capacity was expended each regeneration cycle in attaining the 77% overall MBAS removal for the entire grant period.

TABLE 29

FURNACE OPERATING CONDITIONS
FOR
FOUR BATCH REGENERATION CYCLES

COLUMN	CC-5	CC-5	CC-5	CC-8
CYCLE	First	Second	Third	Fourth
BATCH REGENERATION DATE	12/68	1/70	11/70	7/70
FURNACE FEED Lbs/Hour	286	164	146	142
GAS COMSUMPTION Btu/Lb	1980	2710	3330	3470
HEARTH TEMPERATURE OF				
# 4	1660	1660	1700	1640
# 6	1650	1660	1700	1730

FIGURE 79

ISOTHERMS FOR REGENERATED CARBON

VIRGIN AND THREE REGENERATION CYCLES
OF CC-5, DECEMBER 1968, JANUARY 1970, AND NOVEMBER 1970,
AND FOURTH CYCLE OF CC-8, JULY 1970

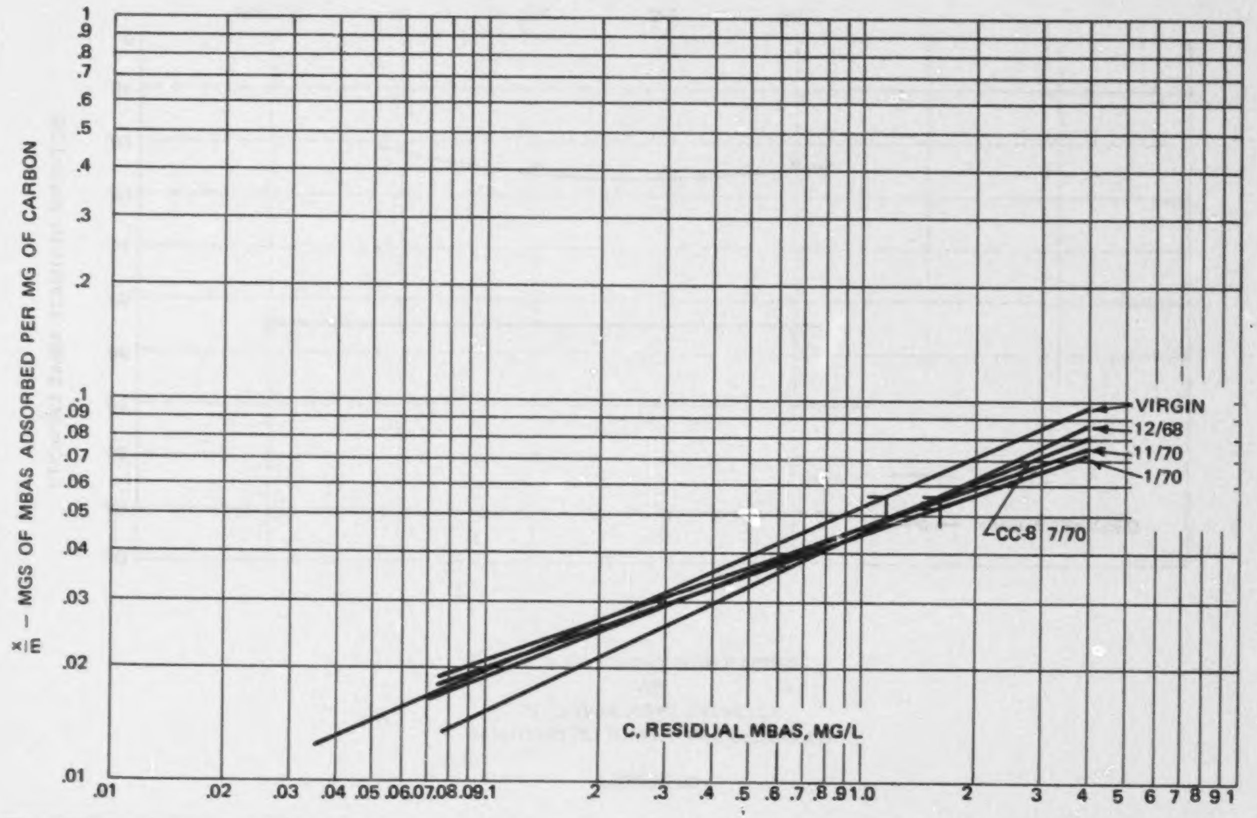


FIGURE 80

ISOTHERM SPENT AND REGENERATED
ULTIMATE MBAS CAPACITY
VS
FOUR REGENERATION CYCLES

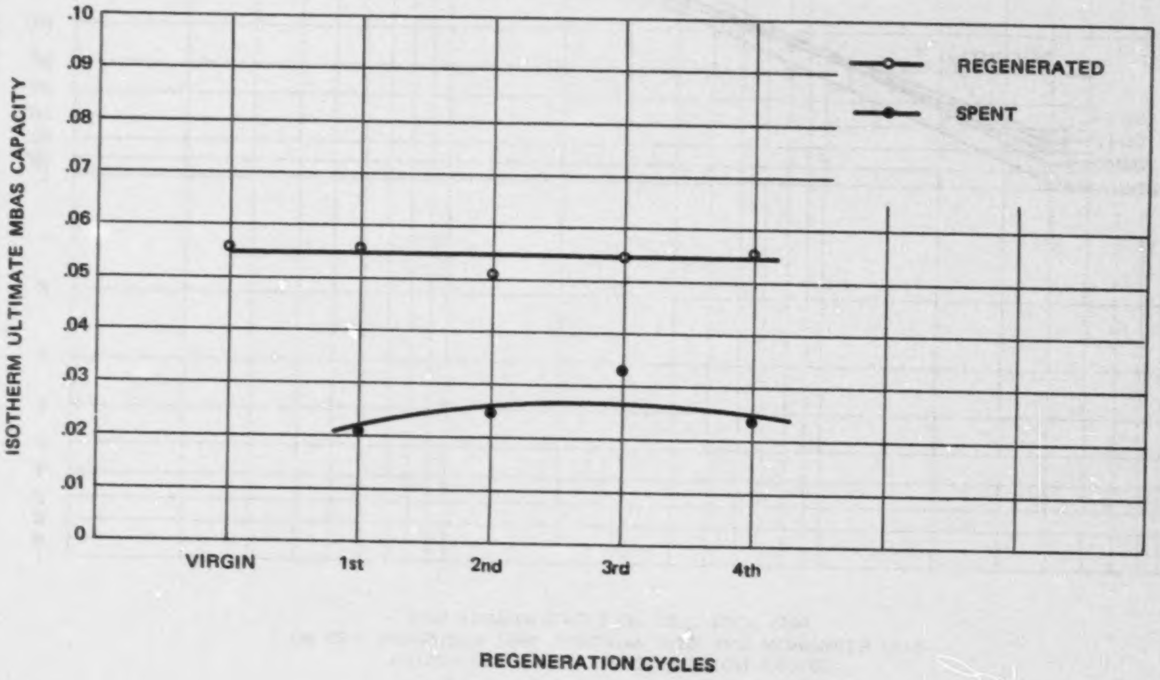
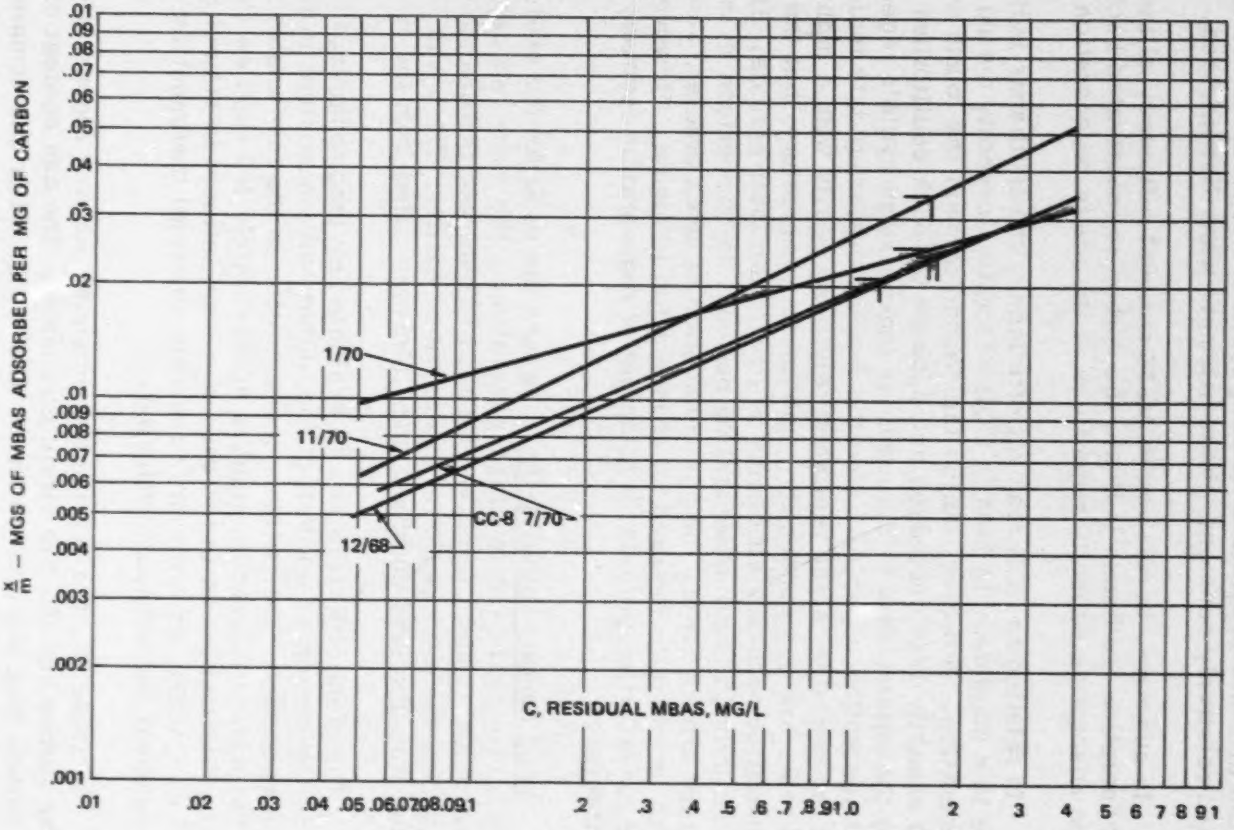


FIGURE 81

ISOTHERMS FOR REGENERATED CARBON

THREE SPENT CYCLES OF CC-5
DECEMBER 1968, JANUARY 1970, AND NOVEMBER 1970
AND FOURTH CYCLE OF CC-8, JULY 1970



During the evaluation of the MBAS isotherms, attempts were made to correllate pounds of MBAS applied and removed, and carbon dosage with ultimate capacity of the spent and regenerated samples. Since the MBAS loadings varied considerably for the regeneration cycles evaluated, and the ultimate capacities for both spent and regenerated samples remained relatively constant, these attempts were discontinued.

In summary, in relation to MBAS removal efficiency of the carbon, the adsorption isotherms indicate the carbon is reactivated back to its virgin adsorption capacity regardless of its age or regeneration cycle.

In relation to COD removal efficiency, the isotherms indicate there is a considerable loss in COD adsorption capacity during the first regeneration. However, during the second through the fourth cycle, the COD capacity loss decreases and appears to reach equilibrium in reactivating the carbon back to the previous regeneration cycle's regenerated COD adsorption capacity. Also the furnace operating data indicates the first regeneration is accomplished relatively easily with a high furnace feed rate, low gas consuption, and hearth temperature, but the net regeneration recovery efficiency is lower than later periods. During the second through fourth regeneration periods, in comparison to the first, the feed rate is lower, the gas consuption is much greater, and the hearth temperature required for regeneration is higher. However, in the later regeneration periods, a much better regeneration recovery efficiency is attained.

Long Range Ash Build-Up. As was the case for the evaluation of organics removal over several regenerations, the same two carbon column historys (CC-5 and CC-6) will be used to evaluate the change in percent ash during the grant period. As described earlier, CC-5 was filled with carbon from the 1968 purchase and CC-6 was filled from the 1965 purchase.

The grant objective was to evaluate any long range build-up of ash in the carbon as a result of the higher calcium content in the carbon column influent. The calcium concentration in the raw wastewater entering the water reclamation plant is approximately 100 mg/l as $CaCO_3$. The calcium concentration in the carbon column influent is around 150 to 160 mg/l as $CaCO_3$, as a result of the lime chemical treatment for phosphorous removal and ammonia stripping.

In Table 30, the percent ash is shown for four regeneration cycles of the carbon and the two virgin purchases. The ash content of the virgin carbon from the 1968 purchase was 5.2%. After one complete regeneration of the column, the average ash content of spent carbon before regen-

TABLE 30

Percent Ash Over Four Carbon Regeneration Cycles

Carbon Column and Regeneration Period Parameter		1968 Purchase Virgin	CC-5 3/31/68 to 10/4/69	CC-5 10/4/69 to 9/18/70	1965 Purchase Virgin	CC-6 11/15/68 to 2/9/70	CC-6 2/9/70 to 11/12/70
Regeneration Cycle		-	1st	2nd	-	3rd	4th
Percent Ash	Spent	5.2	5.7	6.5	4.8	7.0	6.8
	Regenerated		6.4	6.9		7.2	7.1

eration was 5.7%, which might indicate a slight increase in ash content as a result of the higher calcium content in the column influent. However, the greatest increase in ash content was through the regeneration process, as the average ash content of the regenerated carbon was 6.4%. Since the inert portion of the carbon granule would remain the same through the regeneration furnace, the percent increase in ash content indicates a slight amount of the carbon was burned in the furnace. In moving from the first cycle to the second, within the accuracies of the analysis, the first cycle regenerated and the second cycle spent are identical. This would indicate there was no build-up of ash as a result of the calcium in the influent. Again, through the furnace for the second regeneration there was an increase in ash content as a result of burning the carbon, but not as great as the first cycle regeneration.

From the second to the third regeneration cycle, bearing in mind the change in columns and the age of the carbon, but not the type of carbon, the regenerated from the second cycle and the spent from the third are basically identical, indicating no build-up as a result of the calcium. In the third pass through the furnace there was only a slight increase in ash due to burning of the carbon.

From the third to the fourth regeneration cycle, there was a slight decrease in ash content from the third regenerated cycle to the fourth cycle spent. A possible explanation for this is virgin makeup carbon entering the picture. Again, through the furnace there was a slight increase in ash content as a result of burning the carbon.

In summary, it can be concluded, within the accuracies of the analysis, a slight increase in ash can be expected from the calcium content in the influent, for the first regeneration cycle, but the greatest increase can be attributed to burning the carbon in the furnace in the first pass through the furnace. After the first regeneration, the calcium concentration in the influent has no effect on the ash content, and the burning of the carbon in the regeneration process decreases until it is practically negligible for the older carbon. To date, there have been no physical signs of calcium carbonate scale in either the columns or the dried spent carbon.

Carbon Losses Due to Regeneration and Physical Handling. From September 1968 through December 1970 detailed records on carbon regeneration losses and carbon sieve sizes were kept in order to determine the long range carbon losses due to regeneration and physical handling of the carbon. The period included four complete regeneration cycles of the carbon with the carbon from columns Nos. 1, 2, 4 and 5 being completely regenerated two times and columns Nos. 6 and 8 four times. A total of 705,500 lbs. of carbon was regenerated during this period.

Two methods were used to determine the long term losses. First, on the basis of carbon on hand and that purchased during the 2-3/4 years, 7.3% of the carbon was lost. Whereas, if the amount of carbon lost during each regeneration was totalled, the carbon lost over the entire period was 8.9%. Makeup carbon costs, as discussed later in this report, were based on the amount of carbon lost during each regeneration.

Over the entire grant period it was observed that carbon regeneration losses increased with each regeneration cycle, that the activated carbon was becoming smaller with repeated regeneration and that some carbon fines were being released from the carbon columns to the final effluent.

In the following paragraphs the observed increases in carbon regeneration losses and the decreases in carbon particle diameters are discussed in detail.

As pointed out in the discussion of regeneration practices, every effort was made to insure that optimum conditions were present in the furnace and that accurate carbon transfer measurements were made. Despite the efforts of the grant and District personnel carbon regeneration losses continued to increase.

Figure 82 shows the effect of repeated regeneration cycles on carbon losses. An individual point reflects the average loss for a given regeneration cycle. The number within the parentheses indicates the number of batch regeneration periods that occurred within a particular regeneration cycle. The complete regeneration of a given column or columns represents the regeneration cycle. The batch regeneration period refers to the regeneration of a slug of carbon (about 200 ft^3) from the bottom of each column.

Virgin makeup carbon was added five different times during the grant. The first four additions were part of regeneration periods during the grant. Since these four regeneration periods did not reflect regeneration of a normal carbon cycle for that period, the four regeneration periods of virgin carbon were not included in Figure 82; but rather, they are shown in Table 31.

From Figure 82 it appears that when no virgin makeup carbon is added the maximum carbon loss of 10% to 11% is reached after the third

FIGURE 82

PERCENT LOSS OF CARBON
VS
CARBON REGENERATION CYCLES

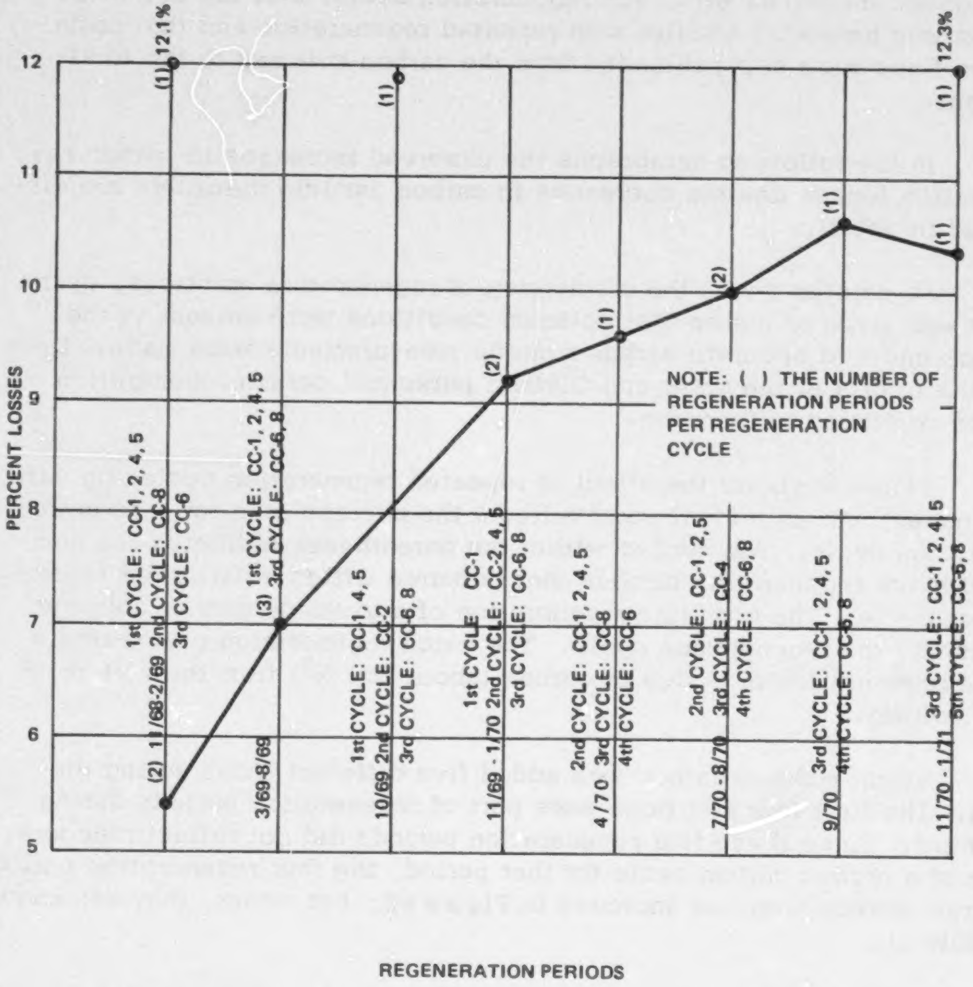


TABLE 31 Carbon Losses

During Batch Regeneration Periods Which Included Regeneration of First Cycle Make-up Carbon

Regeneration Period(1)	Carbon Loss	Amount Originally Added
May 1969	2.5%	not recorded
Feb. 1970	6.2%	333 ft^3
June 1970	5.9%	238 ft^3
July 1970	8.6%	87 ft^3

(1) About 1200 ft^3 of carbon is included in a regeneration period.

to fourth regeneration of the carbon. If makeup carbon were added after each batch regeneration period, to replace the lost carbon, one would expect the carbon losses to fall between 8% and 9% as shown by the last entry in Table 31. Approximately 110 ft^3 of carbon is lost during each batch regeneration period.

Increasing carbon losses with regeneration cycles was also accompanied by an increasing occurrence of carbon fines in the regeneration furnace stack gas scrubber and by decreasing carbon particle diameters.

To help evaluate the physical losses of carbon that occurred during handling and regeneration, sieve analyses were performed on different samples of spent and regenerated carbon. Mean particle diameters were then computed for each sieve analysis.

In Table 32 the average mean particle diameter for spent and regenerated carbon is compared with regeneration cycle and original purchase date. Table 32 shows for both the 1965 and 1968 carbon that the carbon is becoming finer with each regeneration cycle.

Table 32 also shows an apparent shift to coarser particle diameters between the carbon entering the furnace and that leaving the furnace; and at the same time, a shift to finer particle diameters is shown between the hot carbon leaving the furnace and that being returned to the carbon column and eventually being withdrawn once again for regeneration. For example, if one looks at the second cycle 1965 spent carbon entering the dewatering bin just prior to regeneration, this cycle of carbon has an average mean particle diameter of 1.51 mm. After regeneration, but prior to quenching, pumping, and defining, the mean particle diameter of the second cycle hot carbon has increased to 2.02 mm. When this same second cycle carbon is returned to the dewatering bin for its third cycle regeneration, its mean particle diameter has dropped back to 1.58 mm.

Special composite samples were collected during several batch regenerations of carbon column six (1965) in an effort to determine where, between the exit of the hot regenerated carbon and its eventual return as spent carbon to the dewatering bin, the carbon was being broken up. Table 33 shows the results of this special sampling program.

Table 33 once again demonstrates that the finer carbon is being carried out of the furnace with the hot gasses. It also points out that the majority of the decrease in particle size takes place in either the rapid water quench of the hot carbon or in the air diaphram pump-water

TABLE 32

Average Mean Particle Diameters of Carbon From September 1968 to December 1970 Reported in Millimeters

	From Virgin Carbon Purchased in 1965		From Virgin Carbon Purchased in 1968	
Regeneration Cycle	Spent Carbon Entering Dewatering Bin	Regenerated Carbon Prior to Quench	Spent Carbon Entering Dewatering Bin	Regenerated Carbon Prior to Quench
1 st	1.69	-	1.61	1.81
2 nd	1.51	2.02	-	-
3 rd	1.58	1.85	1.43	1.60
4 th	-	-	-	-
5 th	1.44	1.65	-	-
Virgin (Before Defining)	1.58		1.67	

TABLE 33

Mean Particle Diameter of Carbon At Various Points in Regeneration System Reported in Millimeters

Sampling Point	First Cycle Carbon From CC 6 and 8(1)	February 1969 3rd Cycle Carbon From CC-6	November 1970 5th Cycle Carbon From CC-6
Spent Carbon Entering Dewatering Bin	1.69	1.57	1.40
Spent Carbon Entering Furnace	1.70		
Regenerated Carbon Prior to Quench		1.87	1.65
Quenched Regenerated Carbon Entering Defining Tank		1.63	1.46
Defined Regenated Carbon Entering Carbon Column	1.66	1.63	1.40
Virgin Carbon	1.58	1.67(2)	1.70(3)

(1) Calculated from A.Slechta and G.Culp, Progress Report, PHS Demonstration Grant 84-01 "Plant Scale Regeneration of Granular Activated Carbon",April 1 - Oct.1 1965 p. 29

(2) Virgin carbon purchased in January 1968, 121 tons (before defining)

(3) Virgin carbon purchased in May 1969, 15 tons (before defining)

slurry transfer system which moves the quenched carbon to the defining tank. The defining operation and transfer back to the carbon column shows no significant change in mean particle diameter. For further amplification, the sieve analysis of the February 1969 third cycle regeneration is shown in Table 34.

To evaluate where the break-up of the carbon between the carbon furnace and the defining tank might be taking place, an experiment to compare water quenching with air cooling was performed. During the regeneration of carbon column six in April 1970 (fourth regeneration cycle) a hot sample leaving the furnace at 1740°F was split in such a manner that a portion was water quenched in a bucket and a portion was trapped in a dry container and then air cooled. The water temperature in the bucket was 60°F before carbon quenching and 70°F after quenching. Water temperature in the regular quench tank was 66°F at that time. Table 35 indicates that the difference in the two methods of cooling appears to be insignificant. The data in Tables 34 and 35 suggests that the air diaphram carbon slurry pumps and/or the carbon slurry transfer line leading to the defining tank may be responsible for the shift to finer carbon particles.

The decrease in particle size as shown by Table 32 has not caused a noticeable increase in headloss across the carbon columns. In fact, the headloss has been lower to date than it was at the beginning of the grant period.

There has been, however, a noticeable increase of carbon fines build-up in the stack gas scrubber and its water drain. In July 1969 the diameter of the scrubber drain was found to have been reduced from 2 in. to 1/2 in. by a build-up of carbon fines. Since 1966, fourteen batch regeneration periods had occurred prior to this build-up. Six batch regeneration periods later, in March 1970, the scrubber was opened for the first time since 1966 to remove a carbon build-up and the scrubber drain line was again replaced. In July 1970, following four additional batch regenerations, the scrubber again was found to be plugged with carbon fines. Since July 1970 scrubber inspection and cleaning has become part of the routine maintenance prior to carbon furnace start-up. In January 1971, the scrubber drain line was again replaced. Seven batch regeneration periods had occurred since its last replacement in March 1970.

Most of the carbon fines in the final effluent can be related to regeneration periods during which carbon was being removed or added to the carbon columns. These carbon fines have not been detected in Indian Creek Reservoir nor to date have they caused any insurmountable problems with operation of the water reclamation plant or export system.

TABLE 34

Sieve Analysis of Third Cycle Carbon From CC-6 at Various Points In The Regeneration System February 1969

Sampling Point	Percent Retained on Given Sieve						
Sieve No:	4	8	10	16	30	40	50
Spent Carbon Entering Dewatering Bin	0	4.5	15.2	53.2	25.0	1.6	0.3
Regenerated Carbon Prior to Quench	0	8.3	28.3	55.7	7.4	0.1	0
Quenched Regenerated Carbon Entering Defining Tank	0	4.8	17.7	56.0	20.0	0.9	0.2
Defined Regenerated Carbon Entering Carbon Column	0	4.9	19.3	54.0	18.8	1.5	0.3
Virgin Carbon January 1968	0	7.2	-	66.4	24.2	-	2.0

TABLE 35

A Comparison of Water Quenching of 4th Cycle Regenerated Carbon(1) With Air Cooling

Sample	Mean Particle Diameter, mm.
Spent Carbon Entering Dewatering Bin (Composite sample)	1.51
Water Quenching at 60° F Hot Regenerated Carbon Leaving Furnace at 1740° F (grab sample)	1.61
Air Cooling of Sample (same grab sample as water quench)	1.63

(1) Carbon column No. 6, April 1970

Trace amounts of carbon fines will probably always be present in plant effluents where in-house carbon regeneration is practiced.

Should the removal of these carbon fines be necessary, solutions such as more efficient defining, post-filtration, or quiescent settling in reservoirs could be considered. Laboratory and field experience at South Lake Tahoe has shown quiescent settling to be very effective in removing the carbon fines.

Summary and Conclusions. Three years of continuous plant scale granular activated carbon operation with twenty batch carbon regenerations providing four complete carbon regeneration cycles have demonstrated the following:

1. Upflow, countercurrent, granular activated carbon contactors provide the most efficient use of the carbon since only the required amount of the saturated carbon from the lower portion of the column is withdrawn, regenerated, and placed at the top of the column, where it polishes the treated water prior to exit from the column. This enables the use of the more flexible parallel column configuration, and obviates the need for many columns in series.

2. Granular activated carbon was successfully regenerated through four complete regeneration cycles. The organic adsorption ultimate capacity of virgin carbon, as measured by the Iodine Number and COD adsorption isotherms, was not recovered during the first regeneration cycle; however, no additional capacity was lost by subsequent regeneration cycles. The loss in Iodine Number and ultimate COD isotherm capacity did not appear to effect the ability of regenerated carbon to remove COD, BOD, detergents, or color.

3. Except during periods of very low organic loadings a regeneration period was initiated when the percent removal of COD dropped to about 40% or when the carbon column effluent began to reach the export limits for COD and MBAS due to changes in prior treatment upstream. This practice provided satisfactory carbon usage but resulted in variable organic loadings.

4. Eight mils of coal tar epoxy, provided it has the necessary dielectric strength and has been applied correctly, will provide adequate corrosion protection in the carbon columns. Early corrosion problems in two of the columns was caused by improper application of the coating.

5. Unlined iron pipe carbon slurry transfer lines and fittings proved to be satisfactory. None of these lines have been replaced since they were installed in 1965.

6. Perforated screens, when used in the carbon defining tanks, plugged very rapidly, and eventually ruptured. The substitution of Johnson well screens has proved to be very satisfactory.

7. The carbon adsorption system has treated a total of 3,600 million gallons at a carbon dosage of 207 pounds of regenerated carbon per million gallons of flow. The carbon removed an average of 0.38 pounds of COD and 0.021 pounds of MBAS per pound of carbon regenerated. The removal efficiency for COD was 50.8% and 77% for MBAS. The effluent concentrations averaged 10 mg/l for COD and 0.1 mg/l for MBAS.

8. The average carbon furnace feed rate was 176 pounds per hour on the basis of 30 lbs/ft^3. Fuel requirements per pound of carbon averaged 2900 BTU at 860 BTU per cubic foot of natural gas at 18-20 psia. Regeneration temperatures averaged $1670^{o}F$.

9. One manufacturers 8 X 30 mesh carbon was used throughout the grant. The regeneration of this spent carbon brought the average iodine number back from 583 to 802 and the average apparent density from 0.571 gms/ml to 0.487 gms/ml. The ash build-up was 1.8% over three years. By the end of the grant period, carbon purchased in 1965 had been regenerated four complete times and carbon purchased in 1968 (the beginning of the present grant) had been regenerated two complete times.

10. Hourly apparent density tests were used to monitor the regeneration. Carbon furnace feed rate was found to be the most positive means to control the apparent density of the regenerated carbon.

11. For the same long term carbon dosage and applied organic loading, the removal efficiency of the regenerated carbon was not materially affected by the number of regeneration cycles.

12. A controlled loading rate investigation showed that the removal of COD at 2 gpm/ft^2 was substantially better than at either 4 or 6.5 gpm/ft^2, and that MBAS removal was not affected by loading rate. As the columns tested were identical in size and volume, it was not possible to separate the effects of loading rate and contact time. The average efficiencies reported for the entire grant period were at an average loading rate of 4.7 gpm/ft^2.

13. Spent carbon was fed to the carbon furnace at near the design capacity of 6,000 lbs/day at 1600-1650°F during the first regeneration cycles to maintain apparent densities in the 0.48 to 0.49 gm/ml range. Whereas for similar organic loadings during the third and fourth regeneration cycles, feed rates and temperatures of 3400 lbs/day at 1700°F were necessary.

14. In relation to MBAS removal efficiency of the carbon, adsorption isotherms indicate that the carbon is reactivated back to its virgin adsorption capacity regardless of its age or regeneration cycle.

15. The adsorption isotherms indicate that for COD removal efficiency, there is a considerable loss in COD adsorption capacity during the first regeneration. However, during the second through fourth regeneration cycles, the COD capacity loss decreases and appears to reach a point where all the capacity lost during the adsorption cycle is recovered by regeneration. Iodine numbers show the same effect.

16. During the grant period, there were no physical signs of calcium carbonate scale in either the columns or in the dried spent carbon. Ash analyses of the carbon show that prior to the first regeneration there is a slight increase in ash content, possibly due to calcium salts. After the first regeneration cycle the calcium concentration in the water has no effect on the ash content of the carbon.

17. Based on the total amount of carbon on hand and that purchased, 7.3% of the carbon was lost due to regeneration and physical handling during the grant period. Whereas, if the amount of carbon lost during each regeneration period is computed across the furnace and defining tanks, the carbon lost amounts to 8.9%.

18. Carbon losses increased with the number of regeneration cycles. Without the addition of virgin makeup carbon, a maximum carbon loss of 10% to 11% was reached after the third to fourth regeneration of the carbon. If makeup carbon were added after each batch regeneration period to replace the lost carbon, one would expect the carbon losses to be between 8% and 9%.

19. Sieve analyses showed an apparent shift to coarser carbon particle diameters between the carbon entering the furnace and that leaving the furnace. At the same time, a shift to finer particle diameters was observed between the hot carbon leaving the furnace and that being returned to the columns. Other sieve analyses suggest that the decrease in carbon particle diameters was being caused in part by the air diaphram pump in the pumping of quenched carbon to the defining tank.

20. During the grant period, the mean particle diameter of the carbon dropped from 1.69 mm to 1.44 mm.

SECTION XXI

VIRUS REMOVAL

General. One of the most frequently asked questions about the safety of water reuse for purposes involving human contract or ingestion of the water is that of the possible transmission of viral disease. Even though water is not an important mode of transmission of viral disease, and despite the fact that certain sewage and water treatment processes or combinations thereof can remove viruses, wastewater reclamation plants must be properly designed to assure complete virus inactivation or removal.

A review of the water literature reveals many important considerations.

In a 20-month study of the removal of polio virus Type I from water, Robeck, Clarke, and Dostal made several noteworthy ovservations in their paper, "Effectiveness of Water Treatment Processes in Virus Removal", which appeared in the Journal AWWA for October 1962. Their work disclosed clearly that "coagulation and filtration are really one process and must be studied together". This is now a widely accepted and applied principle. They further state, "Though smaller than coliform organisms, the polio virus organism is removed by flocculation and filtration with about the same efficiency as coliforms". They also presented in tabular form a summary of polio virus removal by various water and wastewater treatment techniques as shown here.

They noted that, "If a low but well-mixed dose of alum was fed just ahead of the filters operated at 6 or 2 gpm/sq. ft., more than 98 percent of the viruses were removed by 16 in. of coarse coal on top of 8 in. of sand".

"If the alum dose was increased and conventional flocculators and settling were used, the removal was increased to over 99 percent."

They reported that polyelectrolyte doses to filter influent as low as 0.05 ppm increased floc strength and helped prevent filter breakthroughs of virus. Their results are summarized in the tabulation which follows.

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Summary of Polio Virus Removal

Process	Removal, Per Cent.
Die-off (under experimental conditions-20°C)	≈5-10 in 24-48 hr
Activated sludge	90-95
Polluted stream	99.9 in 18 days
Filtration or seepage	
Through unsaturated sand at 20-40 gpd/sq ft	>99.99
Ground water movement	
Upflow- 9 gpd/sq ft (3 ft/day)	>99.99
Downflow- 12 gpd/sq ft (4 ft/day)	>98
Slow sand filter rates - 50 gpd/sq ft	22-96
Rapid filter rates - 2,880-8,640 gpd/sq ft (2-6 gpm/sq ft)	
Without alum	1-50
With alum	
Without settling	90-99
With settling	<99.7
Flocculation and settling (varies w/dose & time)	95-99
Chlorination (varies w/dose & contact)	99.99

In discussing the above paper, in the same publication, H.O. Hartung had this to say:

"The article by Robeck, Clarke, and Dostal contributes materially to the growing evidence that the public water supply can be processed to remove or inactivate viruses of public health significance. This evidence is consistent with epidemiological studies of waterborne diseases which indicate that viral infections from the use of properly treated public water supplies are unlikely at the present. Both laboratory and epidemiological studies show that the possibility of waterborne viral outbreaks seems to be linked to the presence of gross viral pollution in raw water sources, and to the absence of reliable water treatment procedures at the local water treatment plants for reducing viruses below infectious levels. All of these studies indicate, however, that under circumstances of gross raw water pollution and some existing water treatment methods, a bacteriologically safe water may not be virally safe."

"The article is a very important addition to a series of studies which evaluate unit water treatment processes as to their viral removal capacity. This study has examined filtration. It shows again that surface phenomena are important in the removal of animal viruses from waters. Other studies have indicated that activated sludge sewage processing, chemical coagulation, and chlorination, when properly applied and rigidly controlled, are also factors in virus removal."

"Viral pollution in raw water supplies can be materially reduced through activated sludge processing of sewage prior to disposal in the public raw water supply. Clarke and others observed that 90 percent or more of enteric viruses added to sewage were removed by activated sludge processing in laboratory experimentation. They found that, for a safe water supply, the remaining viruses must be removed by additional processing of the sewage treatment plant effluent or in the public water supply treatment plants. It is important to note that viruses were not significantly removed in primary sewage treatment plants."

"Chlorination under controlled conditions is also effective for viral removal. However, chlorination for bacteria disinfection may not always be a dependable viricide. Free chlorination is considerably more viricidal than combined chlorine. The free residuals required for inactivation depend upon pH, temperature, contact time, and other factors. For example, Kabler and others report that, 'At 25°C and at pH 7, 6 ppm of combined chlorine with a 1-hr contact period was necessary for inactivation of polio virus'. On the other hand, 'Studies indicate that, at a temperature of approximately 20°C and pH values no higher than 8.0-8.5, a free chlorine residual of 0.2-0.3 ppm will destroy most of the tested viruses in 30 min. At temperatures below 10-15°C and pH values greater than 8.5, effective virus kills with free chlorine residuals of 0.2-0.3 ppm are probably not obtainable without long detention periods.' "

"Coagulation in some instances has also been observed to be effective in removing viruses. Chang and others found that two-stage coagulation of Ohio River water - using 25 ppm of alum, and 25 ppm of ferric chloride coagulants with very good floc formation at 25°C, and pH about 7.3 - was effective in removing 99.9 percent of Coxsackie viruses added to water. During such coagulation studies it was observed that coagulant doses adequate for turbidity removal are not necessarily high enough to insure efficient virus or bacterial removal. For virus removal it was found that the dosage of coagulant must be adequate to insure good floc formation, even though such floc might not be necessary for turbidity removal. Also, pH regulation to control speed of floc formation and stirring rate were found to be important."

"In their article the authors prefer to consider coagulation and filtration as one process for virus removal. They show that virus removal is accomplished by good, high strength floc formation followed by filtration. Filter breakthrough was found to be an indication of failure of the combined flocculation-filtration process to remove viruses. Sand filtration at 2 gpm/sq ft was not dependably effective in removing viruses until the water applied to the filters was properly coagulated. The great variability of the effectiveness of sand filtration in certain flow-velocity ranges indicates the weakness of the forces of adhesion between virus and filter media."

In an interesting paper on "High-Quality Water Production and Viral Disease" in the Journal AWWA, October 1962, H. E. Hudson, Jr. reached the following conclusions:

"1. Filtration plants operated to attain a high degree of removal of one impurity tend to accomplish high removals of other suspended materials. Examples of parallelism in removal of turbidity, manganese, microorganisms, and bacteria are cited."

"2. Speed and simplicity make the turbidity measurement a valuable index of removal of other materials. Plants producing very clear water also tend to secure low bacterial counts accompanied by low incidence of viral diseases."

"3. The production of high-quality water requires striving toward high goals as measured by several - not just one or two - quality criteria. These criteria include filtered-water turbidity, bacteria as indicated by plate counts and by presumptive- and confirmed-coliform determinations, and thorough chlorination."

"4. The operating data for plants treating polluted water indicate that low virus disease rates occur in cities where the water treatment operators aim to produce a superior product rather than a tolerable water."

In discussing Hudson's paper, R. L. Woodward made some points which are of interest here. They are as follows:

"Turbidimeters measuring the quality of the output of each filter unit, either continuously or at frequent intervals, are needed to obtain the best possible plant performance."

"If the best effluent clarity is wanted, there is also merit in filtering to waste for a short time after backwashing. This practice has largely been discontinued in this country, but it remains true that water produced during the early part of the filter cycle is not as clear as water produced later. A monitoring turbidimeter can be useful in guiding operations if this practice is followed."

"Although infectious hepatitis is sometimes transmitted by water, there is general agreement among epidemiologists that its principle mode of transmission is by more direct fecal-oral contact. The possible function of water in causing scattered primary cases, which may then give rise to further spread in the community by contact, can only be speculated on."

In the October 1969 Journal AWWA a Committee report by Clarke, Berg, Liu, Metcalf, Sullivan and Vlassoff summarizes very well and completely the status of viruses in water. Excerpts from this report follow:

"Any virus excreted and capable of causing infection when ingested could be transmitted by water. Practical conditions would seem, however, to indicate that we should be concerned with only those viruses that can multiply in the intestinal wall and that are discharged in large numbers in feces. This means that the recognized viruses with which we should be concerned are the members of the enteric virus group: polioviruses, Coxsackie viruses, ECHO viruses, the virus (es) of infectious hepatitis, the adenoviruses, and the reoviruses. The total number of virus types that compose these six major groups is around 100 and, with the exception of the agent(s) of infectious hepatitis, they have been shown present in sewage."

"What can be said about gastroenteritis and the related diarrheal diseases? Many epidemics have been conveniently ascribed to viruses, although very, very few have been thoroughly studied to identify causative agents. Experimental work does, however, indicate that some gastroenteritis or diarrheal disease is caused by viruses and that, under the proper circumstances, it could be waterborne. Weibel and coworkers have listed 142 epidemics of these diseases that occurred in this country from 1946 to 1960, with more than 18,000 persons afflicted. Thus, in terms of number of persons afflicted, gastroenteritis and diarrhea appear quite important. This is an area where laboratory and epidemiological research is obviously needed."

"Finally, something must be mentioned about the unknown, undiscovered, or nonhuman viruses that some scientists have said may be in our water supplies and transmitted through drinking water. Berg has pointed out that viruses native to fish and bacteria abound in water and that plant viruses must be almost as plentiful. He also indicates that viruses native to wild life and farm and domestic animals must also be washed into waterways. The suggestion is then made that, since we know certain viruses can cause cancers in species foreign to them, and that other viruses may infect generically distant hosts, we cannot ignore the large number of viruses of nonhuman origin in our natural waters and be unconcerned that these viruses are probably consumed by man. Of course, we cannot ignore these viruses; they should be studied! There is, however, no reason to panic; there is no reason to suspect that modern water treatment processes cannot remove or inactivate these viruses from our drinking water - if they are present. Certainly, on the basis of all evidence available, the association of cancer viruses in water with the production of tumors in man is not warranted at this time."

"A question repeatedly asked those involved in research on the problem of viruses in water, and probably those involved in supplying the public with drinking water, is 'Is water that meets USPHS bacteriological drinking water standards free from disease-producing levels of virus?' This question can perhaps be answered if the following factors are considered:

1. What are the relative numbers of indicator bacteria and viruses in water and sewage?

2. What is the relative survival time of the two groups of microorganisms?

3. What is the relative effectiveness of water and sewage treatment processes on indicator bacteria and viruses?

4. What epidemiologic evidence do we have that water that meets or does not meet the standards can be responsible for virus disease or infection in humans? "

"Relative numbers of coliform bacteria and enteric viruses in water and sewage have been discussed by Clarke, et al. These authors have calculated coliform-virus ratios to be about 92,000: 1 in sewage and about 50,000: 1 in polluted surface waters. Coliform organisms greatly outnumber enteric viruses in sewage or polluted surface waters and therefore appear to be a far better indicator of pollution than enteric viruses."

"The relative survival times of bacteria and enteric viruses in various types of water have been discussed by Clarke, et al. and by Berg. The data available do not permit generalizations on the comparative survival times of viruses and indicator bacteria. In some waters viruses survive much longer than coliform organisms; in other waters, coliforms survive longer than certain enteric viruses do. Additional studies are needed before any broad generalizations can be made on survival times of viruses and indicator bacteria in water."

"A considerable amount of literature is available regarding the relative effectiveness of water and sewage treatment processes on indicator bacteria and viruses. The viricidal efficiency of water disinfectants has been summarized by Kabler, et al. The conclusions in this paper indicate that different enteric viruses show rather wide variations in their resistance to chlorine. Additionally, certain types of Coxsackie viruses, polioviruses, or ECHO viruses are more resistant to chlorine than indicator bacteria are. This, however, is no cause for alarm. Clarke and Chang have stated that, in the prechlorination of raw water, any enteric virus so far studied would be destroyed by a free chlorine residual of about 1.0 ppm, provided this concentration could be maintained for about 30 min and that the virus was not embedded in particulate material. They further state that, in postchlorination practices where relatively low chlorine residuals are usually maintained, and in water of about 20°C and pH values not more than 8.0-8.5, a free chlorine residual of 0.2-0.3 ppm would probably destroy in 30 min most viruses so far examined. These statements are reassuring, but there still is need for assessing the effect of chlorine on other viruses, particularly the virus(es) of infectious hepatitis, once a reliable method of handling this agent in the laboratory becomes available."

"The effectiveness of chemical flocculation and filtration in removing viruses and bacteria from water has been reviewed by Clarke, et al., and Berg. Chemical flocculation generally seems to be as effective in removing a Coxsackie virus as in removing coliform organisms from water. Slow sand filtration removes both coliform bacteria and enteric viruses quite well but, with increasing filtration rates and no chemical pretreatment, virus removals become erratic. Note also that, although rapid sand filtration also results in a decrease in coliform removals, this decrease is not of the magnitude observed with viruses. This rapid sand filtration is not as effective in removing enteric viruses from water as it is in removing coliforms. Rapid sand filtration, combined with chemical flocculation is, however, effective in removing bacteria and viruses from water."

"The numerous reports of waterborne outbreaks of virus disease have been summarized by Mosley. He states, 'There are very few viruses for which epidemiological evidence suggests transmission by drinking water'. Mosley also states that infectious hepatitis is the only disease caused by an agent having the characteristics of a virus for which evidence of waterborne transmission has been accepted by all workers in the field. A somewhat different feeling, however, has been expressed by Stevenson, who states, 'Unfortunately they (the epidemiologists) have not sharpened their tools to the point where they can tell us the significance of small quantities of viruses in water...' At this point in time, nobody can be sure which of these viewpoints is indeed correct, although true epidemics of waterborne virus disease are extremely rare and are usually the result of a breakdown in treatment procedures, if any treatment is normally used."

"Certainly, waterborne infectious hepatitis does occur, but in the United States most of these outbreaks have been the result of obvious contamination of small, private water supplies. There have been ten reported outbreaks of infectious hepatitis in the United States in which a public supply was involved. In seven of these outbreaks, the reports give no indication of the type of treatment used, if any, or if there was evidence of crossconnection with a toilet or other evidence of definite sewage contamination. In the remaining three outbreaks the supplies were reported chlorinated."

"In the infectious hepatitis epidemic reported by Hayward, no coliform data were presented. Chlorine residuals of 0.7 to 0.9 ppm were reported present in the treated water. All in all, the basis for accepting this epidemic as being waterborne is really inadequate; it has the characteristics of person-to-person transmission."

"Mosley has described an epidemic of infectious hepatitis that apparently was waterborne and that resulted from using an unapproved water source, with coliform MPN's of "240 plus". The major portion of this supply was chlorinated, but there was evidence that the portion of the supply from the contaminated source was never chlorinated and did not have opportunity to mix with the chlorinated portion."

"The epidemic reported by Polkanzer and Beadenkopf is especially interesting, since it seems to be associated with a chlorinated public supply with an excellent record of 'no coliforms'. In the year preceding this epidemic and for 6 months following it, all reported coliform counts were less than 2.2/100 ml. All samples except one, examined about a month after the probable contamination of the water supply, were also negative for coliforms. The one positive sample was collected from a greenhouse tap and had an MPN of 15/100 ml. The treatment plant records indicated 'residual free chlorine levels daily ranged from 0.35 to 0.6 ppm by the orthotolidine test using the flash method'. Other records indicated the plant was meeting the New York State Department of Health recommendations of 'a minimum concentration of free chlorine for a disinfecting period of at least 10 min ranging from 0.2 ppm at a pH of 6.0 to 0.8 ppm at a pH of 10.0'. It appears that, in this epidemic, chlorine residuals (no other treatment was used) were adequate to control the bacteriologic quality of the water. The epidemic has been ascribed to inadequate chlorination, but it is also possible that the virus could have been protected from the chlorine by particulate matter. This epidemic is in some aspects comparable to the New Delhi, India hepatitis disaster. To some, it might appear that treated water may, under certain circumstances, transmit infectious hepatitis. In the reported epidemics, however, it is very doubtful that the water was adequately treated, as it could have been by applying already known procedures."

"There is no doubt that water can be treated so that it is always free from infectious microorganisms-it will be biologically safe. Adequate treatment means clarification (coagulation, sedimentation, and filtration), followed by effective disinfection. Effective disinfection can be carried out only on water free from suspended material. The importance of this latter point has been vividly pointed out by Sanderson and Kelly. They describe a situation in which coliforms were consistently isolated from waters containing from 0.1-0.5 mg/l free chlorine and between 0.7-1.0 mg/l total chlorine after 30 min contact time. This water had turbidity values of from 3.8 to 84 units, contained iron, rust, and occasionally had biological organisms of 2,000 units. Viruses, because of their small size, would probably more easily become enmeshed in a protective coating of turbidity-contributing matter than bacteria would. For most effective disinfection, turbidities should be kept below 1 Jackson Unit; indeed, it would be best to keep the turbidity as low as 0.1 unit, as recommended by AWWA water quality goals. The limit of 5 Jackson Units of turbidity specified in the USPHS 'Drinking Water Standards', 1962, is meant to apply to protected watersheds and not to filtration plant effluents. With turbidities as low as 0.1 to 1, a preplant chlorine feed need be only enough to have a 1 mg/l free chlorine residual after 30 min contact time. Postchlorination practice would depend upon the ability to maintain such residuals throughout the distribution system."

"In conclusion, there does not appear to be cause for panic or overreaction to the problem of viruses in water. Under certain conditions, infectious hepatitis can be transmitted by treated water, but the evidence indicates that in such cases treatment was inadequate. The evidence for the transmission of other enteric viruses by treated water is, for the most part, speculative, with the possible exception of viral gastroenteritis and diarrhea, and nothing much is known about these viruses. These statements, however, do not mean we can be smug or complacent. There is still considerable room for research, both laboratory and epidemiologic, to determine if there is a problem in virus disease transmission by water; to determine if the coliform index is always adequate (positive coliform test may not indicate freedom from viruses); to devise better techniques for measuring viruses in water; to develop a laboratory method of detecting small numbers of viruses in large volumes of water."

Design Considerations For Virus Removal. The preceding literature review points to several factors that must be considered in the design of water reclamation facilities. In the reference section of this report, a total of 29 references are listed relating directly to virus removal. A search of these additional references will reveal several other important items which warrant attention in plant design.

Basically the Tahoe plant is a good secondary sewage treatment plant followed by an efficient water purification plant followed by activated carbon adsorption. On the face of it, then, this process should remove virus based on the experience of numerous existing water works which receive raw water containing raw, primary, or secondary treated sewage. Actually it does more than this because the sewage treatment portions of the plant are designed and the plant is operated with the specific aim of producing a safe water from wastewater. The addition of provisions for adsorption of organics on carbon is another plus factor.

Relating the Tahoe design to the literature quoted, one point is that the close interrelationships of coagulation and filtration have been recognized and utilized in the plant design. A coagulant, alum, is added continuously to the filter influent water following the high lime treatment in such a concentration that maximum filtrability is assured. At times, a polymer is also applied at this point. The mixed-media separation beds in the plant are even more efficient than the coal-sand media tested by Robeck, et al. in removing virus. Recalling the close relationship between virus removal and turbidity reduction which was pointed out by several investigators, it should be mentioned that the Tahoe separation beds have under test produced filtered water with turbidity as low as 0.02 J.U..

Ordinarily, they are operated at about 0.2 J. U. The turbidity of the water is continuously monitored and recorded. Provisions are made to filter-to-waste after each filter backwash as recommended in Woodward's articles. If the water were intended for potable use, then polymer could be used continuously to increase floc strength and to maintain even lower turbidities and to further improve virus removal.

The fact that particulates are almost completely removed minimizes the chance that viruses can escape chlorine contact by encapsulation in particulate matter. Again, if the reclaimed water was intended for potable use, double chlorination with several hours or even days of intermediate contact would provide even further assurance of virus removal.

Also at Tahoe, the pH of the water is lowered to about 7.0 prior to chlorination to improve disinfection efficiency. The high pH of 11.0 in the chemical treatment may also have some benefits in virus removal in addition to its bactericidal effects.

Actual Virus Removals in Plant Operation. Despite the confidence of the designers in the ability of the Tahoe Process to completely remove virus, everyone involved with the project was quite anxious to have this ability confirmed under actual field conditions by appropriate sampling and testing. Fortunately the staff at the WQO laboratory in Cincinnati agreed to cooperate in furnishing information on proper sample collection and transportation of the virus samples to their laboratory, and especially to perform the laboratory tests for virus in the water samples.

Between May 29 and October 2, 1969, nine sets of water samples were collected and submitted to the Cincinnati laboratory for virus examination under the direction of Dr. Gerald Berg. Each set consisted of 4 samples, one each from primary effluent, secondary effluent, carbon column effluent and reclaimed water. Counts in the primary effluent varied from 3 to 207 units. In one sample of secondary effluent, there was no recovery of virus. In the other samples of secondary effluent, the counts varied from 18 to 430 units. Virus were recovered from two of the nine samples of carbon column effluent with counts of 1 and 9 units. All nine tests of the chlorinated reclaimed water were negative for virus. No virus has been recovered from the water being exported to Indian Creek Reservoir in two summers of sampling. While this does not necessarily mean that the water is free of virus, at least all of the results to date are favorable. Table 36 is a tabulation of the 1969 virus testing results. Detailed results for the 1968 sampling are not tabulated, but all chlorinated reclaimed water samples were negative for virus. Admittedly this is only a small amount of data, but in an area where the total test data are meager, any bit of information is helpful.

TABLE 36

VIRUS SAMPLING - 1969

SOUTH TAHOE PUBLIC UTILITY DISTRICT

WATER RECLAMATION PLANT

	Virus Recovered (PFU)**				
Date	Primary effluent	Secondary effluent	Carbon Column effluent (U)	Final effluent(C)	Sample size(liters)+
May 29	3	0	1	0	1P,S,U,C
June 5	--	--	0	0	2P,S,U,C
June 12	--	--	0	0	2P,S,U,C
Aug.20	3	18	NRD*	0	4P,4S 20U,20C
Aug.27	--	--	NRD	0	12C
Sept. 11	--	--	0	0	27U, 19.7C
Sept. 18	179	14	9	0	4P,4S, 29U,29C
Sept. 25	NRD	430	0	0	4S, 32U, 32C
Oct. 2	207	320	0	0	4P,4S, 32U,32C

* No reliable data

+ P=primary, S=secondary, U=unchlorinated final, C=chlorinated final

** Tests performed by the FWPCA Laboratory at Cincinnati, Ohio

PFU=Plaque forming units

Complete virus removal or inactivation at Tahoe is finally dependent upon adequate chlorination. Again, this parallels bacterial removal which is also dependent on chlorination to complete the task. In both cases, complete disinfection cannot be successfully carried out without proper pretreatment of the water by clarification, removal of chlorine demanding substances, and adjustment of pH to a low range favorable for best use of chlorine. Successful disinfection in the presence of ammonia, the usual condition in treating wastewater, depends to a very great extent upon the use of rapid, violent, and thorough mixing of the chlorine solution and the water being treated, as well as adequate chlorine dosages. Less chlorine is required for viral and bacterial disinfection of wastewater than might be estimated based upon its ammonia content. At Tahoe the application of only 2 mg/l of chlorine is adequate to produce the results reported in the presence of 2 to 15 mg/l of ammonia nitrogen.

In addition to attempts to recover virus from reclaimed water, epidemiological data is also needed. The use of reclaimed water for supplemental drinking water supply as presently practiced in Windhoek, South Africa should yield a great deal of extremely valuable results along this line.

SECTION XXII

DISINFECTION

General. To make water suitable for many types of reuse, it must be adequately disinfected.

In the disinfection of water chlorination depends on several factors including:

1. Time of contact.
2. Concentration of disinfectant.
3. Concentration of organisms.
4. Temperature of disinfection.
5. Concentration of interfering substances.
6. pH of the water.
7. Chlorine application and mixing procedures.

Primary and secondary treated effluents contain particulate matter and have high chlorine demands which interfere with chlorination and make it impossible to properly disinfect such waters. Advanced wastewater treatment (AWT) as practiced at Tahoe eliminates these interferences and makes it possible to completely destroy bacteria, virus, and other organisms. Chemical coagulation, settling, and filtration remove particulate matter which could otherwise prevent contact between chlorine and the organisms. Specifically, the turbidity of the separation bed effluent is about 0.2 J.U. as compared to 10 to 50 for secondary effluent and 20 to 80 for primary effluent.

AWT also greatly reduces the concentration of organisms to be killed, thus enhancing the disinfection process. Secondary effluent can contain 2 million or more coliforms per 100 ml as compared to 20 to 200 per 100 ml in the carbon column effluent at Tahoe prior to chlorination.

AWT also reduces markedly the concentration of other substances which interfere with chlorination. Activated carbon adsorbs organics which would otherwise exert considerable chlorine demand and thus interfere.

The tertiary effluent still contains ammonia nitrogen in concentrations of 2 to 20 mg/l. Despite the reactions which occur between ammonia and chlorine in water, good disinfection is secured. This was an unexpected result. This efficiency probably is explained by the influence of the rapid, violent, and thorough mixing of the chlorine with the reclaimed water which is provided.

A chlorine concentration of only about 2 mg/l is required for disinfection of the tertiary effluent as compared to 20 mg/l or more commonly used in treating primary and secondary effluents.

As previously mentioned, the complete removal and destruction of bacteria and other organisms from wastewater depends ultimately on proper disinfection with chlorine more than any other single factor, as it does in water purification practice.

When chlorine is added to water containing ammonia-nitrogen, the ammonia reacts with the hypochlorous acid formed by the addition of chlorine to produce chloramines. Further addition of chlorine to the "breakpoint" converts the chloramines to nitrous oxide, an insoluble gas which is released from the water to the atmosphere. Equations illustrating these reactions are given below:

$$NH_3 + HOCl \rightleftharpoons NH_2Cl + H_2O \quad \text{monochloramine}$$

$$NH_3 + 2HOCl \rightleftharpoons NHCl_2 + H_2O \quad \text{dichloramine}$$

$$NH_2Cl + NHCl_2 + HOCl \rightleftharpoons N_2O + 4\ HCl$$

To reach the "Breakpoint" and to complete the conversion of all ammonia-nitrogen to nitrous oxide, about 10 mg/l of chlorine must be applied to the water for each one mg/l of ammonia-nitrogen present in the wastewater at the point of chlorine application. Based on a chlorine cost of 0.0365 per pound, the chemical cost for ammonia removal by breakpoint chlorination is about $3 per million gallons of water treated for each mg/l of ammonia-nitrogen removed. It is obviously rather expensive to treat waters high in ammonia by this method. For example, water containing 15 mg/l of ammonia would cost $45 per million gallons for complete treatment by this process. However, the cost for removing 0.5 mg/l of ammonia-nitrogen by this means is only $1.50 per million gallons, as the required chlorine to ammonia ratio does not change at extremely low concentrations. Trace amounts can be removed at the same proportionate cost as larger amounts of ammonia. This ability of breakpoint chlorination to remove trace amounts of ammonia to zero concentration is unique. Other nitrogen removal processes either cannot remove the ammonia completely, or can remove trace amounts only at greatly increased costs as compared to costs for securing the initial reduction in concentration. For this reason, regardless of the method used for removing the bulk of the nitrogen, breakpoint chlorination will undoubtedly be used as a supplemental process to remove the last traces of ammonia where this is necessary.

Chlorine Feed Facilities. Chlorine is purchased and fed from ton containers. There are three chlorinators installed each with a maximum capacity of 2,000 pounds per day, or a total of 6,000 pounds per day. The three chlorinators are connected to distribution headers in such a way that chlorine solution may be applied to each or all of four points in the treatment process. Ordinarily it is applied only to two points, (1) to the activated sludge mixed liquor in a splitter box preceding secondary settling to control filamentous growths and nitrifiers, and (2) to the carbon column (final) effluent. In the final effluent pump sump there is a chlorine solution distribution header which introduces the chlorine to the reclaimed wastewater between the inlet to the wet well and immediately adjacent to the final effluent pump suction lines. The turbulence in the wet well and passage through the turbine pumps provides the excellent rapid mixing of the chlorine and the water which is essential to good utilization of chlorine in the presence of ammonia. Chlorine contact is provided in 27 miles of pipeline and a one million gallon equalizing reservoir (covered steel tank) as the water is pumped in two stages to Indian Creek Reservoir. Chlorine may also be fed for odor control to the raw sewage in the plant influent rising well, or to the separation bed influent, if necessary to extend filter runs and to aid in maintaining clean filter media in the separation beds.

Results of Chlorination. Chlorine has been used at times at all four points of application. Dosages of 2 to 5 mg/l to the raw sewage when necessary have controlled odors at this point in treatment. Dosages of 1 to 8 mg/l to the activated sludge mixed liquor have prevent filamentous growths and have also helped (along with maintaining a high load factor) in maintaining nitrogen in the ammonia form for improved stripping efficiency by controlling the growth of nitrifying bacteria in the return activated sludge. It has been necessary to use chlorine ahead of the filters on only one or two occasions for one or two days to assist in cleaning the beds. By far the most important aspect of the utilization of chlorine has been in the disinfection of the finished water. The use of about 2 mg/l of chlorine has produced excellent results in eliminating bacteria, virus, and other organisms from the exported water. After two years of plant operation, in 1970, in recognition of the good bacteriological record and other measures of plant performance, the various State of California regulatory agencies, including the State Water Resources Control Board and the State Department of Health, approved Indian Creek Reservoir (the receiver for reclaimed water) for all water contact sports including swimming, boating, fishing, water skiing, and the like, and the reservoir has in fact been used for all these purposes to some extent even prior to completion of planned recreational facilities at the site.

Table 37 summarizes the bacteriological test results from April 1968 through December 1970.

The tabulation of bacteriological data reveals several items of interest. First of all, the bacteriological quality is excellent and from this standpoint of quality, as well as from many others, it is unquestionably the best ever produced by a full-scale wastewater treatment plant anywhere. It is also of interest to note the improvement in the consistency in bacteriological removal which has occurred in the 33 months of continuous plant operation. This is due to the perfection of operator skills as they gained experience in operation of the plant. This same improvement is also reflected in other results of plant operations as will be described later in this report.

For 8 of the 33 months all bacteriological samples collected during the month were found to be free of coliform bacteria. From June 15, 1970 through September 29, 1970, a period of 107 consecutive days, a total of 105 bacteriological samples were collected, all of which were found to be free of coliform organisms.

Despite this excellent record, there is still room for some further improvement in bacteriological quality. If reclaimed water is to be recycled to supplement water supplies used for potable purposes then there are two simple additional steps which could be taken to add further safety and reliability in this regard. One is retention time following the initial chlorine treatment. The more time the better. A few hours would be good, a few days even better. Then, the water could be again chlorinated. Such a sequence of double chlorination with intermediate storage would provide fail-safe disinfection satisfactory for any proposed water reuse from the standpoint of bacteriological quality.

TABLE 37

MONTHLY SUMMARY OF BACTERIOLOGICAL TESTS

	Number of Samples							
		With Coliform MPN/100 ml of						
Month	Total	less than 2.2 or 2.0	2.1 or 2.2	5.1, 5.0, or 4.4	8.8 or 9.2	15 or 16	more than 16	24 or 38
1968								
April	13	11	1	0	1	0	0	0
May	23	15	1	3	0	1	3	
June	17	15	1	1	0	0	0	0
July	23	12	1	1	0	0	7	0
Aug.	21	9	4	1	0	1	6	0
Sept.	21	19	1	0	0	0	1	0
Oct.	23	14	1	2	0	2	4	0
Nov.	14	14*	0	0	0	0	0	0
Dec.	17	14	2	1	0	0	0	0
1969								
Jan.	19	17	1	1	0	0	0	0
Feb.	20	16	0	3	0	0	1	0
March	25	22	1	2	0	0	0	0
April	22	21	1	0	0	0	0	0
May	21	20	1	0	0	0	0	0
June	21	18	1	1	0	0	1	0
July	22	17	3	2	0	0	0	0
Aug.	21	20	0	1	0	0	0	0
Sept.	17	17*	0	0	0	0	0	0
Oct.	31	30	0	0	1	0	0	0
Nov.	30	30*	0	0	0	0	0	0
Dec.	30	24	5	1	0	0	0	0
1970								
Jan.	31	30	1	0	0	0	0	0
Feb.	24	24*	0	0	0	0	0	0
March	31	29	0	0	1	0	0	1
April	30	27	2	0	0	0	0	1
May	31	31*	0	0	0	0	0	0
June	30	29	0	2	0	0	0	0
July	31	31*	0	0	0	0	0	0
Aug.	29	29*	0	0	0	0	0	0
Sept.	30	29	0	0	1	0	0	0
Oct.	31	26	0	2	1	2	0	0
Nov.	30	30*	0	0	0	0	0	0
Dec.	31	28	1	0	1	0	0	1

* All bacteriological samples collected during the month were found to be free of coliform organisms.

SECTION XXIII

FINISHED WATER QUALITY

Sampling and Analysis. Previous sections of this report describe in detail the methods and frequency of all sampling and analyses for the project, and report the results of bacteriological and virus tests. This section reports and interprets the results of chemical and other tests which have been made during 33 months of operation of the 7.5 mgd plant.

Included in the results are concentrations in the reclaimed water of BOD, COD, SS, MBAS, turbidity, pH, chlorine residual, nitrogen (ammonia, nitrate, and nitrite), phosphorus, alkalinity, hardness, chloride, and sulfate. The daily results have been tabulated on a form for each month together with plant flow data. The monthly reports of daily results from April 1968 through December 1970 form Appendix B to this report.

In addition, monthly summaries have been prepared which compare a few parameters of plant performance with the quality standards as established by the Lahontan Regional Water Quality Control Board and Alpine County. The monthly summaries of plant effluent quality data have been condensed, six months to a page, in Tables 38 through 43.

Laboratory analyses were also made of water samples collected at various stages in the treatment process to show the efficiency of individual units within the plant. Tests were made on raw sewage and primary, secondary, separation bed, and carbon column effluents. These results are summarized in Tables 44 through 49 for 3 month periods beginning in July 1968 to January 1, 1970. These tables show average, median, maximum and minimum values for each quarter.

To show the effectiveness of various unit processes and their consistency, or lack of it, the data for the calendar year 1969 from the preceding tables have been plotted in Figures 83 through 88. In looking at the BOD removals through the plant in Figure 83, note that the average BOD of the chlorinated carbon column effluent is 1.0 mg/l or 99.5% removal as compared to an average of 28 mg/l and 80% removal in the activated sludge effluent. Even though the maximum BOD of secondary effluent reached 83 mg/l the final product never contained more than 4.9 mg/l.

Table 38

SOUTH TAHOE PUBLIC UTILITY DISTRICT
ADVANCED WASTE WATER TREATMENT PLANT

RECLAIMED WATER QUALITY
April - Sept. 1968

DESCRIPTION	APRIL			MAY			JUNE			JULY			AUGUST			SEPTEMBER		
	Per Cent of Time			Per Cent of Time			Per Cent of Time			Per Cent of Time			Per Cent of Time			Per Cent of Time		
	50	80	100	50	80	100	50	80	100	50	80	100	50	80	100	50	80	100
MBAS, mg/l, less than	.01	.03	.06	.13	.17	.28	.13	.17	.24	.12	.18	.20	.18	.19	.19	14	.16	.19
BOD, mg/l, less than	1.3	2.9	4.8	1.9	3.3	3.5	4.5	5.4	6.4	0.4	1.1	2.2	0.5	0.9	1.5	0.4	0.8	1.4
COD, mg/l, less than	18	21	22	11	16	19	7	10	12	13	17	18	13	15	17	9	10	13
SUSP. S.,mg/l, less than	2*	5*	11*	0	2	5	0	1	4	1	2	7	0	1	3	0	1	2
TURBIDITY,JU, less than	1.3	1.6	2.0	0.6	0.7	1.3	0.4	0.5	1.0	0.3	0.5	1.0	0.1	0.2	0.3	0.1	0.2	0.4
PHOSPHORUS,mg/l, less than	0.4	0.5	0.7	1.0	2.3	2.7	1.0	1.3	1.6	1.2	1.7	1.8	0.4	0.7	1.2	0.10	0.14	0.8
pH, units, range	7.6 to 9.0			6.6 to 7.9			6.9 to 8.2			7.0 to 8.1			7.0 to 8.4			6.8 to 7.7		
Coliform bacteria MPN/100 ml, Median,	less than 2.2			less than 2.2			less than 2.2			less than 2.2			less than 2.2			less than 2.2		
Plant Flow, million gals.	55.1			60.8			72.4			82.8			76.7			58.2		

* Carbon fines from new carbon columns

Table 39

SOUTH TAHOE PUBLIC UTILITY DISTRICT
ADVANCED WASTE WATER TREATMENT PLANT

RECLAIMED WATER QUALITY
OCTOBER 1968 to MARCH 1969

DESCRIPTION	OCTOBER 1968			NOVEMBER			DECEMBER			JANUARY 1969			FEBRUARY			MARCH		
	Per Cent of Time			Per Cent of Time			Per Cent of Time			Per Cent of Time			Per Cent of Time			Per Cent of Time		
	50	80	100	50	80	100	50	80	100	50	80	100	50	80	100	50	80	100
MBAS, mg/l, less than	0.09	0.09	0.09	0.13	0.15	0.26	0.11	0.13	0.15	0.16	0.28	0.35	0.20	0.27	0.28	0.11	0.13	0.20
BOD mg/l, less than	1.0	1.4	3.2	0.3	1.2	2.0	0.5	0.6	0.8	1.6	2.9	3.1	1.6	1.6	1.6	0.9	1.5	1.7
COD, mg/l, less than	12	17	20	15	17	23	7	11	13	11	13	19	11	16	25	9	12	16
SUSP. S., mg/l, less than	0	0	1	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0
TURBIDITY, JU, less than	0.3	1.4	1.9	1.4	1.7	2.9	0.9	1.1	1.7	1.5	2.7	6.2	0.7	1.2	3.0	0.3	0.4	0.3
PHOSPHORUS, mg/l, less than	0.15	0.53	0.64	0.42	0.75	4.9	0.10	0.46	0.52	0.15	0.26	0.54	0.13	0.31	0.49	0.22	0.28	0.31
pH, units, range	6.8 to 8.8			6.9 to 9.1			6.5 to 7.8			6.4 to 8.9			6.6 to 7.4			6.6 to 8.5		
Coliform bacteria MPN/100 ml, Median	less than 2.2			less than 2.2			less than 2.2			less than 2.2			less than 2.2			less than 2.2		
Plan Flow, million gals.	48.3			46.4			49.8			69.0			53.9			57.5		

Table 40

SOUTH TAHOE PUBLIC UTILITY DISTRICT
ADVANCED WASTE WATER TREATMENT PLANT

RECLAIMED WATER QUALITY
April - Sept. 1969

DESCRIPTION	APRIL			MAY			JUNE			JULY			AUGUST			SEPTEMBER		
	Per Cent of Time			Per Cent of Time			Per Cent of Time			Per Cent of Time			Per Cent of Time			Per Cent of Time		
	50	80	100	50	80	100	50	80	100	50	80	100	50	80	100	50	80	100
MBAS, mg/l, less than	0.09	0.11	0.13	0.16	0.25	0.27	0.09	0.12	0.14	0.19	0.21	0.23	0.10	0.15	0.27	0.04	0.12	0.14
BOD, mg/l, less than	0.5	0.7	1.1	0.5	0.9	1.0	0.9	1.5	4.1	0.7	0.8	1.8	0.8	1.0	4.9	1.1	1.7	3.8
COD, mg/l, less than	5	7	11	10	12	15	7	9	10	13	15	19	7	13	16	8	10	15
SUSP. S., mg/l, less than	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TURBIDITY, JU, less than	0.2	0.3	0.8	0.4	0.6	1.0	0.1	0.4	0.8	0.3	0.6	1.0	0.2	0.4	0.8	0.1	0.2	0.4
PHOSPHORUS, mg/l, less than	0.21	0.39	0.49	0.21	0.58	0.70	0.16	0.23	0.86	0.11	0.29	1.1	0.07	0.09	0.90	0.08	0.12	0.24
pH, units, range	6.6 to 8.5			6.8 to 8.1			6.7 to 8.8			6.6 to 9.4*			6.5 to 8.1			6.8 to 7.4		
Coliform bacteria MPN/100 ml, Median	less than 2.2			less than 2.2			less than 2.2			less than 2.2			less than 2.2			less than 2.2		
Plant Flow, million gals.	76.8			63.9			81.0			75.9			82.3			61.9		

* Only one reading above 8.8

Table 41

SOUTH TAHOE PUBLIC UTILITY DISTRICT
ADVANCED WASTE WATER TREATMENT PLANT

RECLAIMED WATER QUALITY
OCTOBER 1969 to MARCH 1970

DESCRIPTION	OCTOBER			NOVEMBER			DECEMBER			JANUARY 1970			FEBRUARY			MARCH		
	Per Cent of Time			Per Cent of Time			Per Cent of Time			Per Cent of Time			Per Cent of Time			Per Cent of Time		
	50	80	100	50	80	100	50	80	100	50	80	100	50	80	100	50	80	100
MBAS, mg/l, less than	0.09	0.20	0.20	0.19	0.35	0.35	0.00	0.13	0.18	0.07	0.09	0.09	0.10	0.14	0.14	0.24	0.25	0.53
BOD, mg/l, less than	0.9	1.3	1.4	1.0	2.5	3.9	0.5	1.8	6.7	0.3	0.4	2.4	2.2	2.8	5.0	2.2	3.3	4.5
COD, mg/l, less than	3.9	7.8	12.8	9.0	10.4	21.7	8.9	11.3	24.0	5.7	13.3	18.1	7.3	11.5	20.7	12.2	18.5	30.7
SUSP. S., mg/l, less than	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TURBIDITY, JU, less than	0.2	0.3	0.8	0.4	0.5	1.3	0.3	1.0	1.5	0.7	1.0	1.8	0.3	0.4	0.6	0.4	0.8	1.1
PHOSPHORUS, mg/l, less than	0.12	0.16	0.29	0.06	0.12	0.27	0.13	0.20	0.68	0.19	0.51	0.75	0.19	0.27	0.43	0.15	0.21	0.63
pH, units, range	6.7 to 8.1			6.6 to 8.7			6.6 to 8.3			7.4 to 8.4			7.1 to 8.2			6.5 to 8.1		
Coliform bacteria MPN/100 ml, Median	less than 2.0			less than 2.0			less than 2.0			less than 2.0			less than 2.0			less than 2.0		
Plant Flow, million gals.	55.6			50.2			63.9			87.0			65.5			71.7		

Table 42

SOUTH TAHOE PUBLIC UTILITY DISTRICT
ADVANCED WASTE WATER TREATMENT PLANT

RECLAIMED WATER QUALITY

APRIL - SEPTEMBER 1970

DESCRIPTION	APRIL			MAY			JUNE			JULY			AUGUST			SEPTEMBER		
	Per Cent of Time			Per Cent of Time			Per Cent of Time			Per Cent of Time			Per Cent of Time			Per Cent of Time		
	50	80	100	50	80	100	50	80	100	50	80	100	50	80	100	50	80	100
MBAS, mg/l, less than	0.25	0.35	0.35	0.30	0.45	0.46	0.35	0.42	0.46	0.21	0.24	0.40	0.10	0.15	0.22	0.19	0.21	0.25
BOD mg/l, less than	2.7	2.9	5.0	4.7	4.7	4.8	2.1	2.8	2.9	1.1	2.0	4.3	0.7	1.2	3.5	0.7	1.4	2.6
COD, mg/l, less than	13.3	16.2	18.3	12.6	17.2	22.7	12.6	14.8	24.5	14.8	17.0	28.7	10.5	13.3	20.0	9.6	10.5	12.5
SUSP. S., mg/l, less than	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TURBIDITY, JU, less than	0.5	0.5	1.0	0.3	0.5	1.0	0.5	1.0	2.0	0.3	0.7	1.0	0.3	0.3	0.4	0.2	0.2	0.3
PHOSPHORUS, mg/l, less than	0.07	0.09	0.19	0.09	0.15	0.30	0.12	0.32	0.61	0.25	0.46	0.75	0.24	0.39	0.65	0.06	0.09	0.20
pH, units, range	6.4 to 7.8			6.7 to 8.3			6.8 to 7.9			7.0 to 8.9			6.8 to 8.3			6.8 to 8.3		
Coliform bacteria MPN/100 ml, Median	less than 2.0			less than 2.0			less than 2.0			less than 2.0			less than 2.0			less than 2.0		
Plant Flow, mill'on gals.	61.6			66.5			75.5			85.3			93.6			74.1		

Table 43

SOUTH TAHOE PUBLIC UTILITY DISTRICT
ADVANCED WASTE WATER TREATMENT PLANT

RECLAIMED WATER QUALITY
OCTOBER - DECEMBER 1970

DESCRIPTION	OCTOBER			NOVEMBER			DECEMBER		
	Per Cent of Time			Per Cent of Time			Per Cent of Time		
	50	80	100	50	80	100	50	80	100
MBAS, mg/l, less than	0.11	0.14	0.17	0.10	0.17	0.23	0.32	0.41	0.52
BOD mg/l, less than	1.1	1.2	1.7	0.80	1.2	1.7	1.2	1.4	2.1
COD, mg/l, less than	8.1	10.0	13.2	6.8	8.9	14.3	14.8	18.7	26.0
SUSP. S., mg/l, less than	0	0	0	0	0	0	0	0	0
TURBIDITY, JU, less than	0.2	0.2	0.2	0.2	0.2	0.6	0.3	0.6	0.7
PHOSPHORUS, mg/l, less than	0.04	0.06	0.39	0.08	0.12	1.0	0.09	0.12	0.20
pH, units, range	6.9 to 7.6			6.9 to 8.1			6.9 to 7.7		
Coliform bacteria MPN/100 ml, Median	less than 2.0			less than 2.0			less than 2.0		
Plant Flow, million gals.	64.0			62.0			70.7		

Table 44

SUMMARY OF LABORATORY ANALYSES(1)

8 July 1968 - 1 October 1968

Parameter	Raw Sewage		Primary Eff.		Secondary Eff.		Chem.Clar. Eff.		Sep. Bed Eff.		Carbon Col. Eff.	
mg/l	Ave.	Range	Ave.	Range	Ave.	Range	Ave.	Range	Ave.	Range	Ave.	Range
P	12	5 - 21	13(2)	5 - 22	10	5 - 13	0.7	0 - 5			0.7	0 - 3
NH_3			21	12 - 27	7	1 - 12					7	0.8-9
NO_3	0.01	0-0.03									7	6 - 10
NO_2	0.02	0-0.03									2	1 - 4
MBAS	7	4 - 9			0.5	0.2-0.8			0.4	0.2-0.6	0.15	0.1-0.2
COD	281	144-371	217	110-320	37	17-57			18	10-31	12	2 - 18
BOD			97	38-164							6 0.7(4)	1 - 8 0.01-2
Alk. as $CaCO_3$					167	145-210					232	146-275
Ca Hardness as $CaCO_3$	43	33-56	67(3)	33-82							144	10 197
Susp. Solids	233	118-590	100	32-268	26	1-111					0	
Color (Units)									20	15-25	<5	0 - 5

1. Average daily flow 2.30 mgd. Range 1.60 to 3.05

2. $CaPO_4$ wasted to primary for part of period

3. Lime centrate returned to primary

4. Following chlorination

Table 45

SUMMARY OF LABORATORY ANALYSES
1 October 1968 to 1 January 1969

Parameter	Raw Sewage		Primary Eff.		Secondary Eff.		NH3 Strip.Tow.Eff.		Sep. Bed Eff.		Carbon Col.Eff.	
mg/l	Av.	Range	Av.	Range	Av.	Range	Av.	Range	Av.	Range	Av.	Range
PO_4 - P	9	2-14	7	3-14					0.5	0.04-3	0.5	0.02-5
NH_3 - N					17	14-21						
NO_3 - N	0.43	0-1.7									0.17	0-0.6
NO_2 - N	0.09	0.05-0.2									0.1	0-0.5
MBAS	8	5-11	6	5-10					0.7	0.2-1.2	0.17	0.1-0.8
COD			184	128-281					23	13-29	12	2-25
BOD	175	125-250	120	96-152							0.8 (2)	0.1-3 (2)
Total Alk.as $CaCO_3$	184	156-228									233	113-427
Hardness as $CaCO_3$	76	44-114							146	92-184	134	44-200
Susp.Solids	250	62-674	126	24-390	12	4-29			3	0-22	2	0-23
Color (Units)									13	5-20	5	5

1. Average daily flow 1.57 mgd. Range 0.76 to 2.42 mgd

2. Chlorinated effluent

Table 46

SUMMARY OF LABORATORY ANALYSES
1 January 1969 to 1 April 1969

Parameter	Raw Sewage		Primary Eff.		Secondary Eff.		Recarb. Eff.		Sep. Bed Eff.		Carbon Co.Eff.	
mg/l	Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range
PO_4 - P	6	3-10	7 (3)	2-11	5	1-9			0.3	.02-.6	0.2	.01-.5
NH_3 - N					15.6	11-21						
NO_3 - N	0.3	.1-.8									0.2	0-.5
NO_2 - N	0.08	.03-.2									0.06	0-.5
MBAS			5	4-7	2	1-4			0.6	.3-1.2	0.13	.02-.3
COD	156	110-210	158	100-235	53	31-88	38	34-47	20	12-37	10	3-19
BOD	144	112-160	108	84-147	18	10-24			3	1-5	0.8 (2)	.3-1.7 (2)
Total Alk.as $CaCO_3$	161	108-234									248	131-340
Hardness as $CaCO_3$	69	44-120							144	50-188	124	54-178
Susp. Solids	156	51-500	77	42-182					1.6	0-10	0.4	0-2
Color (Units)									9	4-15	5	2-5
Turbidity SJU											0.5	.1-1.1

1. Average daily flow 2.21 mgd. Range of average daily flows: 1.26 to 6.02 mgd
2. Chlorinated effluent
3. Lime centrate returned to primary

Table 47

SUMMARY OF LABORATORY ANALYSES
1 April 1969 to 1 July 1969

Parameter	Raw Sewage			Primary Effluent			Secondary Effluent			Sep. Bed Effluent			Carbon Column Eff.		
mg/l	avg.	med.	range	avg.	med.	range	avg.	med.	range	avg.	med.	range	avg.	med.	range
PO_4-P	7.4	7.2	4-13	7.7(3)	8.0	3-11	6.9	7.2	4 - 9	.2	.2	.02-.6	.2	.2	.02-.6
NH_3-N							14	14	11-18						
NO_3-N	.46	.32	0-2.6				.60	.28	0-2.5						
NO_2-N	.09	.09	.03-.2				.16	.04	.01-.9				.18	.08	0 -.8
MBAS				4.9	4.9	2 - 8	1.8	1.9	.4-3.2	.3	.3	.1-.7	0.15	0.10	0 -.3
COD				173	155	86-723				15	15	10-20	7.7	7.4	3-19
BOD	140	127	110-265	75	78	31-105	20	20	7-28	2.6	3.0	1 - 4	(2).8	.8	.2-1.5
Total Alkalinity as $CaCO_3$	166	163	119-288				183	182	150-261				214	218	134-283
Hardness as $CaCO_3$	77	78	48-118							127	135	64-150	126	126	74-152
Susp. Solids	233	206	60-660	76	62	16-228	15	12	4-44	2	0	0-11	.5	0	0-7
Color (Units)										6	6	4-10	3	3	2-5
Turbidity(SJU)													.3	.3	.1-1.2

1. Average daily flow 2.5 mgd. Range of average daily flows: 1.7 to 3.8 mgd.
2. Chlorinated effluent.
3. Lime centrifuge centrate returned to primary.

Table 48

SUMMARY OF LABORATORY ANALYSES
1 July 1969 to 1 Sept. 1969

Parameter	Raw Sewage			Primary Effluent			Secondary Effluent			Sep. Bed. Effluent			Carbon Column Eff.		
mg/l	avg.	med.	range	avg.	med.	range	avg.	med.	range	avg.	med.	range	avg.	med.	range
PO_4-P	8.5	8.5	4.6-15.8	9.8(3)	9.9	6.4-12.9	8.9	8.6	4.6-14.2	.2	.1	0-1.14	.16	.08	0-1.14
NH_3-N	19.7	19.6	16.1-22.5				20.9	21.1	15.8-25.9				13.5	13.4	2.9-18.
NO_3-N	.39	.23	0-5.5				1.6	.91	0 - 5.5				2.4	1.8	0-7.8
NO_2-N	.08	.06	0-.5				0.29	.13	0- 5.0				.23	.14	0-.62
MBAS				6.0	5.8	2.6-9.6	2.0	1.8	.4-5.2	.85	.52	.12-4.2	.13	.12	0-.27
COD				238	230	60-465	57	54	4-128	17.5	15.4	9.4-36	9.5	8.2	3.2-18.
BOD	140	140	103-172	88	93	58-112	33	30	23-52	2.2	2.2	.4-6.8	(2)1.2	.8	.2 - 4.
Total Alkalinity as $CaCO_3$	177	159	122-276				188	186	141-227				204	205	102-262
Hardness as $CaCO_3$	71	60	42-160							126	138	50-188	131	136	38-174
Susp. Solids	167	136	37-936	117	76	12-800	24	16	0-248						
Color(Units)										9	7	4-27	4	4	1-10
Turbidity(SJU)													.3	.2	.1-1.0

1. Average daily flow 2.4 mgd. Range of average daily flows: 1.8 to 2.9
2. Chlorinated effluent.
3. Lime centrifuge centrate returned to primary.

Table 49

SUMMARY OF LABORATORY ANALYSES
1 Oct. 1969 to 1 Jan. 1970

Parameter	Raw Sewage			Primary Effluent			Secondary Effluent(5)			Sep. Bed Effluent			Carbon Column Eff.		
mg/l	avg.	med.	range	avg.	med	range	avg.	med.	range	avg.	med.	range	avg.	med.	range
PO_4-P	10.7	10.6	3.6-20.4	10.8(3)	10.6	6.1-17.9	8.7	8.8	2.8-17.9	.15	.12	0 - .7	.12	.11	0 - .7
NH_3-N	21.0	20.6	13 -30				21.1	20.8	11-28	14(4)	13.1	6 - 22	17.4	16.8	8 -28
NO_2-N	.08	.08	.02-.23				.06	.04	0 - .3				.11	.07	0 -.39
NO_3-N	.34	.28	0 -2.1				.22	.12	0-1.4				.84	.48	0 -3.9
MBAS				6.1	6.0	3.1-7.8	3.1	3.7	.2 - 6				.13	.11	0 -.4
COD				210	208	59-420	98	78	16-321	19.8	16.9	9-68	8.0	7.8	.6-24
BOD	134	130	79-229	115	110	78-140	42	36	20-83	2.5	2.1	.1-5.8	1.3(2)	.9	.2-3.9
Total Alkalinity as $CaCO_3$	199	193	114-285				189	190	110-293				233	230	156-356
Hardness as $CaCO_3$	106	106	60-146							161	162	96-204	151	156	108-178
Susp. Solids	232	204	24-608	107	88	16-376	33	25	1-124	0			0		
Color (Units)										11	10	5 -28	5	5	3 - 15
Turbidity (SJU)													.4	.3	.1 -1.5

1. Average daily flow 1.85 mgd. Range of average daily flows: 1.07 to 3.37 MGD
2. Chlorinated effluent
3. Lime centrifuge centrate containing PO_4-P returned to primary
4. Ammonia stripping tower effluent - data includes values when tower wasn't running
5. Biological upset

FIGURE 83

BOD REMOVALS THROUGH PLANT — 1969

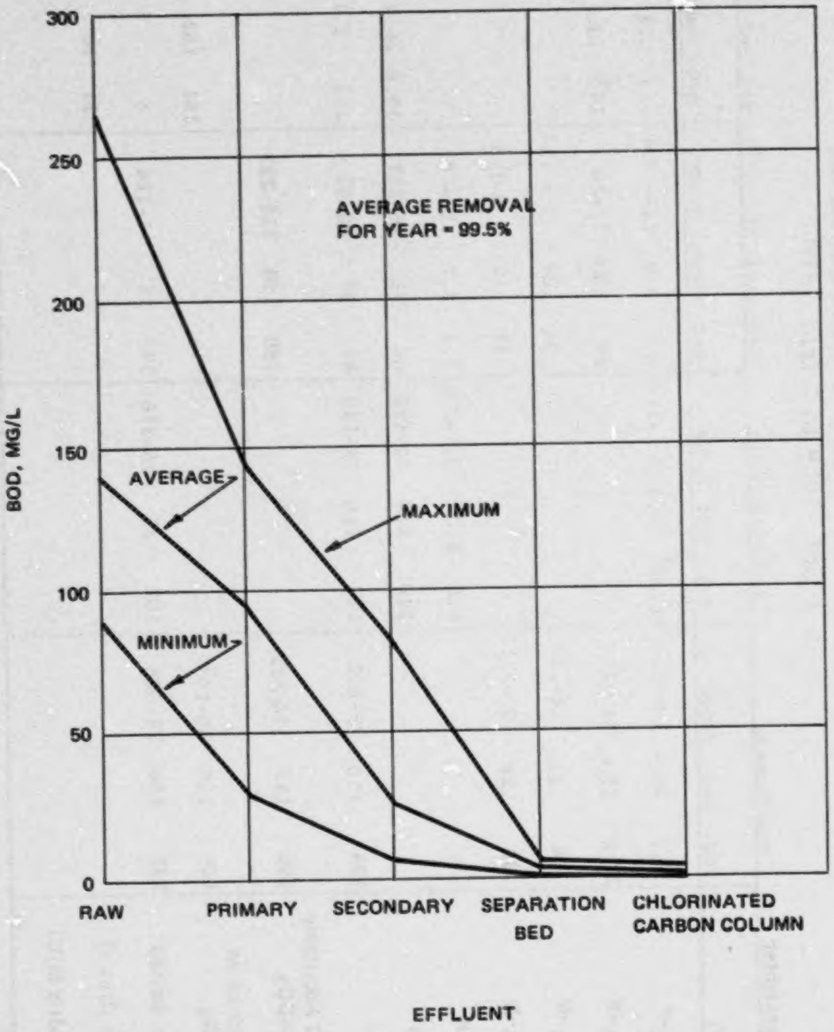


FIGURE 84

COD REMOVALS THROUGH PLANT - 1969

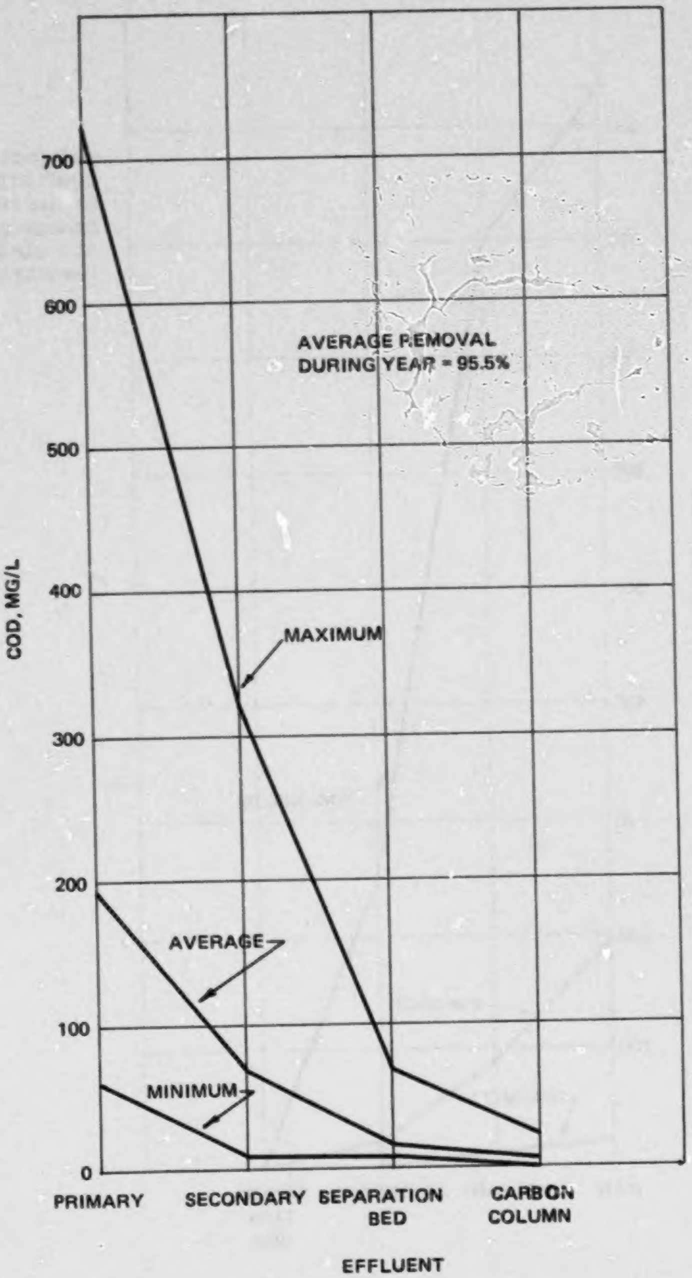
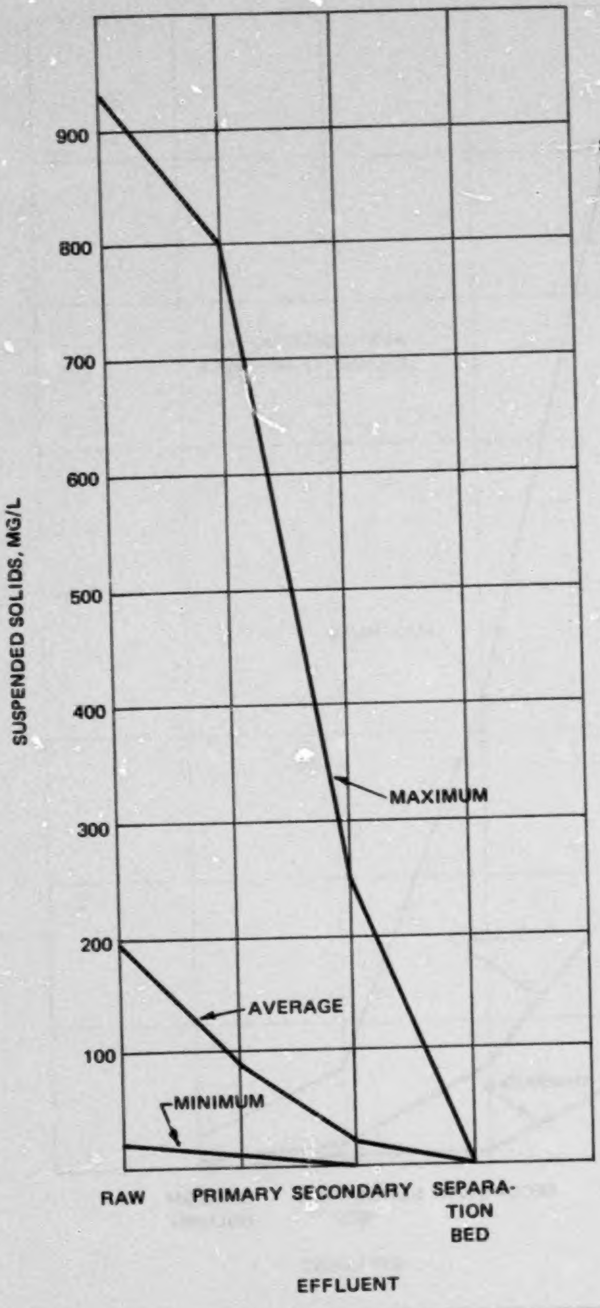


FIGURE 85

SUSPENDED SOLIDS REMOVAL THROUGH PLANT - 1969



SUSPENDED SOLIDS ARE COMPLETELY REMOVED BY THE FILTERS, BUT CARBON COLUMNS WILL ADD CARBON FINES TO THE WATER AT TIMES.

FIGURE 86

MBAS REMOVALS THROUGH PLANT - 1969

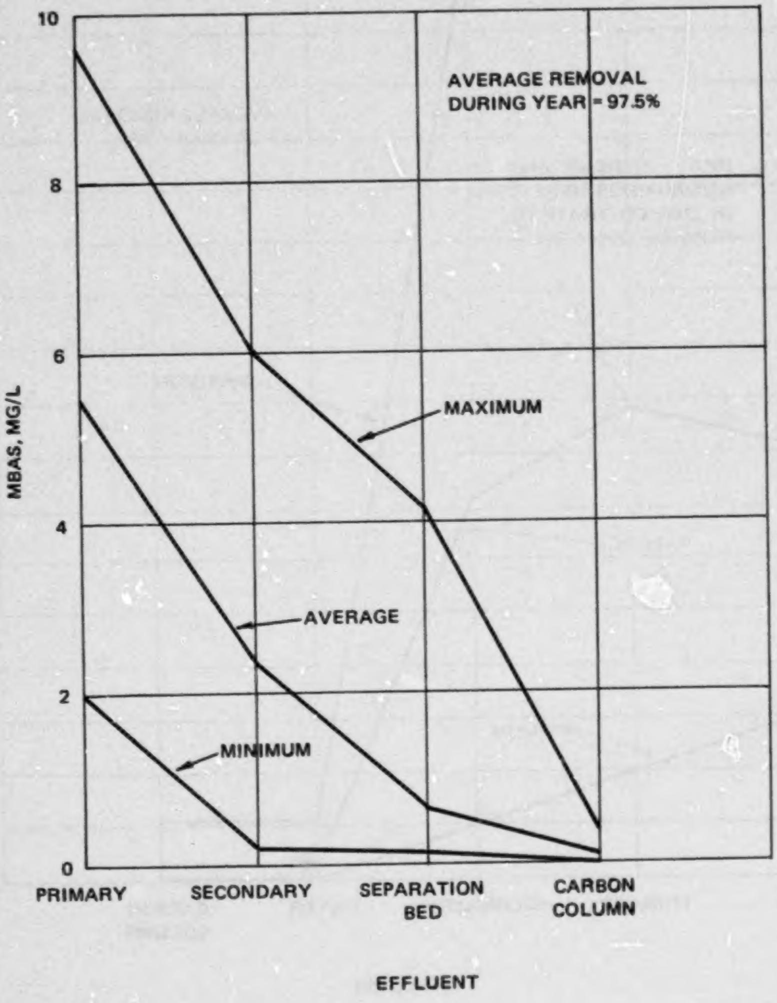


FIGURE 87

PHOSPHORUS REMOVAL THROUGH PLANT
1969

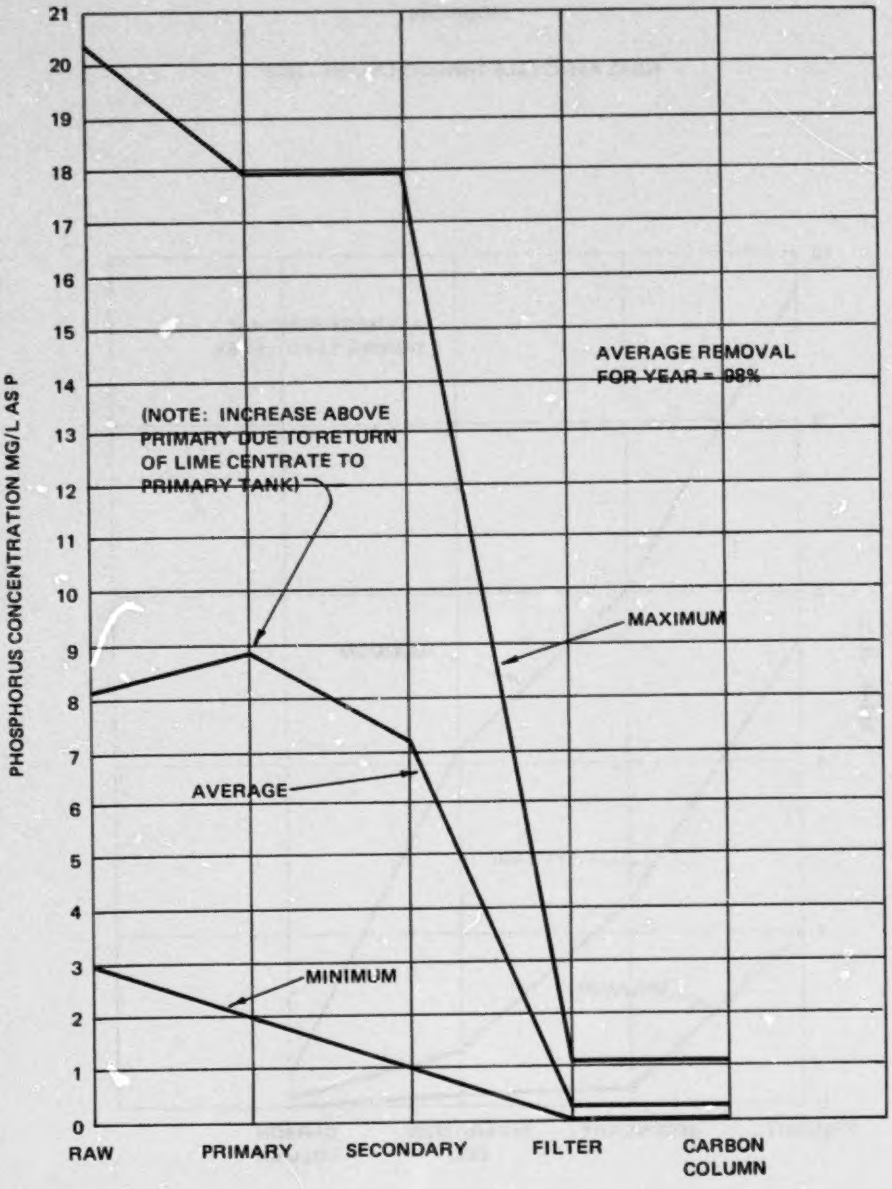
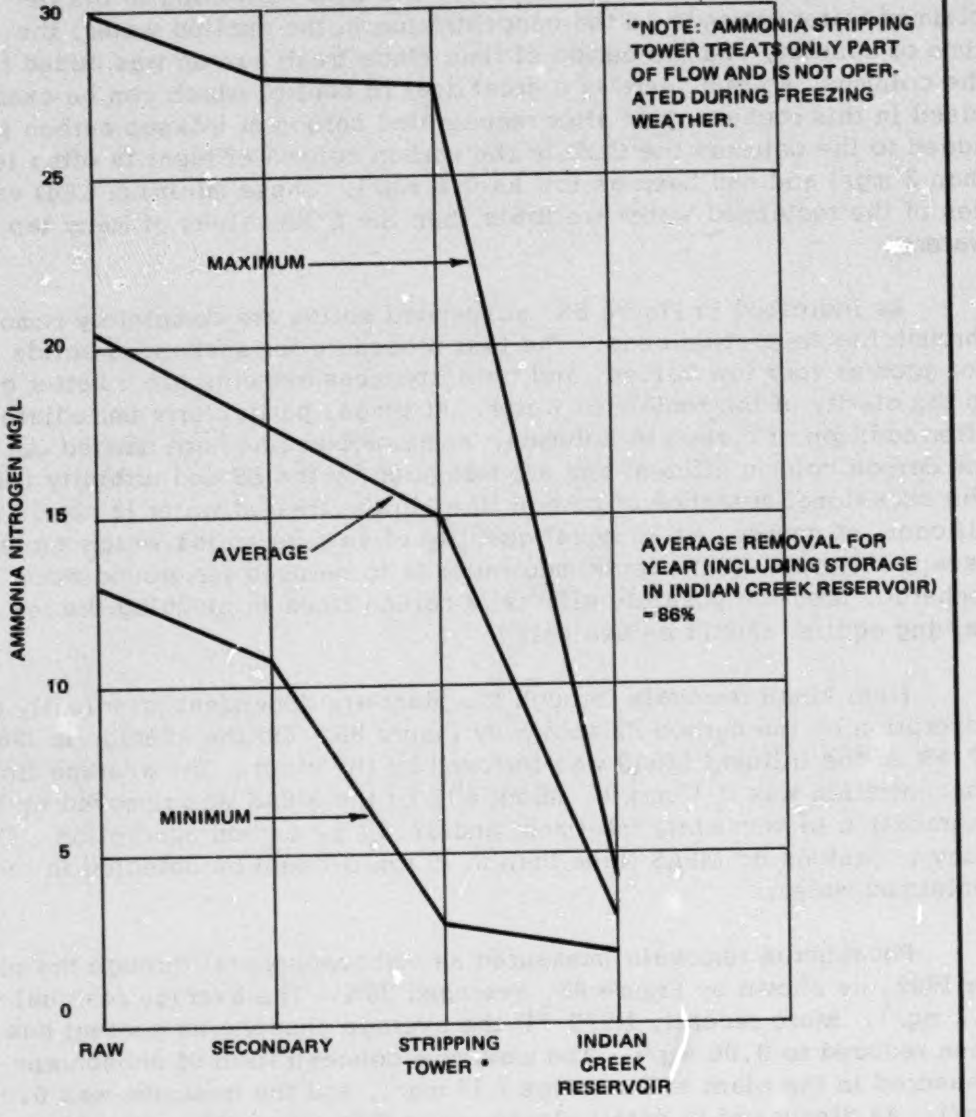


FIGURE 88

AMMONIA NITROGEN REMOVALS THROUGH PLANT AND RESERVOIR – 1969



*NOTE: AMMONIA STRIPPING TOWER TREATS ONLY PART OF FLOW AND IS NOT OPERATED DURING FREEZING WEATHER.

AVERAGE REMOVAL FOR YEAR (INCLUDING STORAGE IN INDIAN CREEK RESERVOIR) = 86%

The much greater consistency and reliability of the treatment in the tertiary section of the plant and the greater ease of operation of this part of the plant are even more apparent from day to day observation of plant operations than from the curves.

Figure 84 shows the COD removals through the plant. The average residual COD for 1969 was 8.8 mg/l which represents an average removal of 95.5% during the year. The COD remaining in the reclaimed water depends on the concentration in the applied water, the time of contact, and the period of time since fresh carbon was added to the columns, so that there is a great deal of control which can be exercised in this regard. Just after regenerated carbon or makeup carbon is added to the columns the COD of the carbon column effluent is often less than 3 mg/l and had been as low as 0.6 mg/l. These minimum COD values of the reclaimed water are lower than the COD values of many tap waters.

As indicated in Figure 85, suspended solids are completely removed through the separation beds. The test procedure for suspended solids is not good at very low values, and turbidity measurements are a better guide to the clarity of the reclaimed water. At times, particularly immediately after addition of carbon to columns, some carbon fines are carried out in the carbon column effluent and are measured by the SS and turbidity tests. The occasional presence of carbon fines in the treated water is not as significant, of course, as an equal quantity of sewage solids which might escape removal. If the reclaimed water is to be used for ground water recharge, then the possible effects of carbon fines in plugging the receiving aquifer should be evaluated.

High MBAS removals through the plant are dependent principally upon adsorption by the carbon as shown by Figure 86. On the average in 1969, 97.5% of the influent MBAS was removed by the plant. The average final concentration was 0.13 mg/l. About 60% of the MBAS was removed by biodegradation in secondary treatment and 37.5% by carbon adsorption. On many occasions no MBAS (less than 0.00 mg/l) could be detected in the reclaimed water.

Phosphorus removals (measured as orthophosphate) through the plant for 1969, as shown by Figure 87, averaged 98%. The average residual was 0.2 mg/l. More recently (1970-71) the average phosphorus content has been reduced to 0.06 mg/l. The maximum concentration of phosphorus measured in the plant effluent was 1.14 mg/l, and the minimum was 0.00 mg/l. As discussed in detail elsewhere in this report, the experience and skill of the operators as well as subtle changes in treatment are important in reducing phosphorus concentrations from 2.0 mg/l, which is easily obtained, to the 0.06 mg/l value which is now the average. The removal of phosphorus is one operation which is better at full plant scale than it was in pilot plant tests.

Figure 88 shows the removals of ammonia nitrogen through the plant plus Indian Creek Reservoir. As shown by the curves the average removal during 1969 in the plant was about 25% and in Indian Creek Reservoir another 61% was removed. When the stripping tower was operating and plant flows were within its design capacity ammonia nitrogen removals as high as 90% were obtained through the plant alone. The average nitrate nitrogen in the plant effluent was 0.9 mg/l, and the average for nitrite nitrogen was 0.01 mg/l.

To summarize, the typical quality of reclaimed water now (1971) being produced by the Tahoe plant is shown in Table 50, together with a comparison of these results with those from secondary treatment.

TABLE 50

TYPICAL QUALITY OF RECLAIMED WATER

	% Average Removals		
Parameter	Secondary Treatment	Tertiary Treatment	Tertiary Treatment, Aver. final content (mg/l unless shown)
BOD	85	99.8	0.7
COD	65	96.0	9
MBAS	60	98.0	0.15
Suspended Solids	89	100.0	0
Color	Incomplete	100.0	< 5 units
Odor	Incomplete	100.0	None
Phosphorus	10	99.5	0.06
Turbidity	96	99.9	0.6 Ju
Coliforms MPN/100 ml	95	99.99+	< 2.0

Summary - Finished Water Quality. The 7½ million gallon a day water reclamation plant has been in continuous operation since March 31, 1968, with the exception of the nitrogen removal tower, which was completed in November of 1968. The plant has been operating without interruption for the entire period. The quality of water is excellent and has exceeded at all times the high standards set by the regulatory agencies. During the first three years of operation, the plant processed more than 2.5 billion gallons of wastewater from which the following materials were removed:

(1) 72 tons of detergent (MBAS)

(2) 2,250 tons of suspended solids

(3) 150 tons of phosphorus

(4) 2,550 tons of oxygen consuming substances

(5) All color, odor, and coliform bacteria

All of the solid materials removed from the wastewater have been incinerated at temperatures of 1,200 to 1,600° F. to insoluble, sterile ash.

About 2,000 tons of lime mud and 260 tons of spent activated carbon have been reclaimed and reused in the treatment process.

The reclaimed water quality has without exception exceeded the requirements of the export standards.

While there were no regulatory requirements for removal of phosphorus or nitrogen, phosphorus was removed in order to restrict algae growths in Indian Creek Reservoir which receives the reclaimed water. For the first few months of plant operation, phosphorus concentrations in the reclaimed water ranged from 0.5 to 2.0 mg/l. Operations have been steadily improved, and currently the average final phosphorus content is in the range of 0.06 mg/l. The phosphorus level has been low enough at all times to secure the desired control of algal growth in the Reservoir. Action within the Reservoir itself has kept nitrogen levels well within acceptable limits.

In December, 1969 following close observation of 9 months operation of the plant and after consultation and receipt of recommendations from the California State Department of Health, the Lahontan Regional

Water Quality Control Board formally approved and authorized use of Indian Creek Reservoir for "unrestricted recreational purposes" including fishing, boating, water skiing, swimming and other water contact sports. Previously the water had been used for irrigation of alfalfa, hay, and pasture land.

There is no question that the water could also be used for any domestic, municipal, agricultural, or recreational use that does not involve drinking of the water or food processing packaging.

The high quality of the water, which technically meets the U. S. Public Health Service Drinking Water Standards, and the fact that sewage treatment plant effluents inadvertently find their way into water supply sources in many instances, invariably raises the question of the possible reuse of the reclaimed water as a supplemental source of public water supply. There is some logic in this question, certainly, since intentional reuse has an advantage over inadvertent reuse in that water renovation techniques are applied with the idea of reuse in mind. Also continuous recycle to supplement potable water supplies would be limited to about one-third of the total supply, as this procedure would avoid progressive increases in total dissolved solids and the need to add a costly demineralization process to advanced wastewater treatment. Planned reuse can and should provide a time barrier by storage of reclaimed water to allow monitoring, analysis, and diversion, if necessary, in case of accidental spills.

Unfortunately, this question of possible potable reuse of reclaimed wastewater creates in the mind of the great majority of people a great and immediate barrier, based on aesthetics, to any consideration of beneficial reuse of the water whatever. This reaction tends to obscure the primary purposes and usefulness of advanced wastewater treatment, which are complete elimination of water pollution and health hazards and the reuse of reclaimed water for purposes other than for potable water in order to free an equal quantity of high quality water for potable supply.

Indications are that water of quality suitable as a supplemental source of supply for potable water purification plants can be produced from wastewater by advanced treatment systems. However, much further study is needed of the tolerable levels of biological and chemical substances that may be present in wastewater; such as trace elements, pesticides, carcinogens, antibiotics, hormones, viruses, and materials not yet studied. The effects of various commercial and industrial wastes found in many urban wastewaters also need considerable investigation. The findings of studies in these areas will also be valuable in evaluating the safety of badly polluted surface water supply sources.

Obviously, some hazardous industrial wastewaters either alone or mixed with domestic sewage will present special problems in reclamation, or will even prevent certain reuse.

These and a number of other good reasons favor delaying the use of reclaimed water for drinking until there is absolute necessity to do so. Morbidity and mortality data for populations using water supplies which conform to the U. S. Public Health Service Drinking Water Standards support the reliability of these finished water standards as applied to supplies taken from ground and surface water sources, since acute health effects have not yet been attributed to waters that have met these standards. Questions that have been raised on chronic health effects of drinking such water are currently being investigated only to a very limited degree , and funds are needed to greatly expand this work.

The U.S.P.H.S. Drinking Water Standards are based on the premise of sanitary survey of the raw water source to assure that the supply was taken from"the most desirable source which is feasible, and effort should be made to control pollution of the source. If the source is not adequately protected by natural means, the supply shall be adequately protected by treatment". As water sources become increasingly polluted, more data can be obtained on the applicability of the Drinking Water Standards to various dilutions of wastewater. These data, if collected, will be valuable in developing criteria, monitoring techniques, and standards for the safety of reclaimed wastewater, since the Drinking Water Standards may not be applicable in this situation.

Delay in the use of reclaimed wastewater to supplement water supply sources will also gain time in which to further establish the reliability and consistency of plant scale water reclamation treatment processes, as well as time in which to secure further reduction in the costs of water reclamation.

It is possible that situations will develop in the future where wastewater must be reclaimed to increase drinking water supplies but in the meantime the reclamation processes will continue to undergo rapid and substantial improvement, which will result in greater reliability and confidence in them, and better public acceptance, when the time comes that they must of necessity be used to supplement drinking water supplies.

Also, in the interim, reclaimed water can be used to satisfy other needs, and high quality water supplies can be reserved for production of drinking water .

SECTION XXIV

INDIAN CREEK RESERVOIR

General. Out of the ten years of research and development and the three years of demonstration at South Tahoe, the single most important fact revealed is that algal growths in Indian Creek Reservoir (which is composed almost entirely of reclaimed water) have, in actual practice, been controlled effectively by nutrient removal. The importance of this basic fact must not be lost in reviewing the great mass of detailed laboratory and plant data which is presented herein.

There will continue to be discussions as to precisely why there are no nuisance algal blooms, or specifically what was done that prevented such growths, but there is no longer any question whatever that proper treatment of wastewater can provide satisfactory control of algae - this has been demonstrated conclusively.

It is the unanimous judgement of the project personnel that phosphorus removal alone is the key to the successful limitation of algae in the reclaimed water. Nitrogen, carbon, and dissolved organics must also receive some consideration under certain conditions, but it appears that these substances are not effective stimulants when phosphorus concentrations are less than about 0.3 mg/l.

Study and Monitoring Procedures. Indian Creek Reservoir was studied in three ways: (1) general observation, (2) limited sampling and testing program under this grant, and (3) a detailed scientific study by the Lake Tahoe Area Council (LTAC) through their Board of Consultants, Dr. P. H. McGauhey, Dr. E. A. Pearson, and Dr. G. A. Rohlich and their project staff, Dr. D. B. Porcella, Dr. G. L. Dugan, and Dr. E. J. Middlebrooks. This third phase of the work was done under a separate grant from the Environmental Protection Agency.

The first phase of study, that of general observation of the appearance of the Reservoir, is the most important phase because it determines the degree of public and political acceptance which the Reservoir and the

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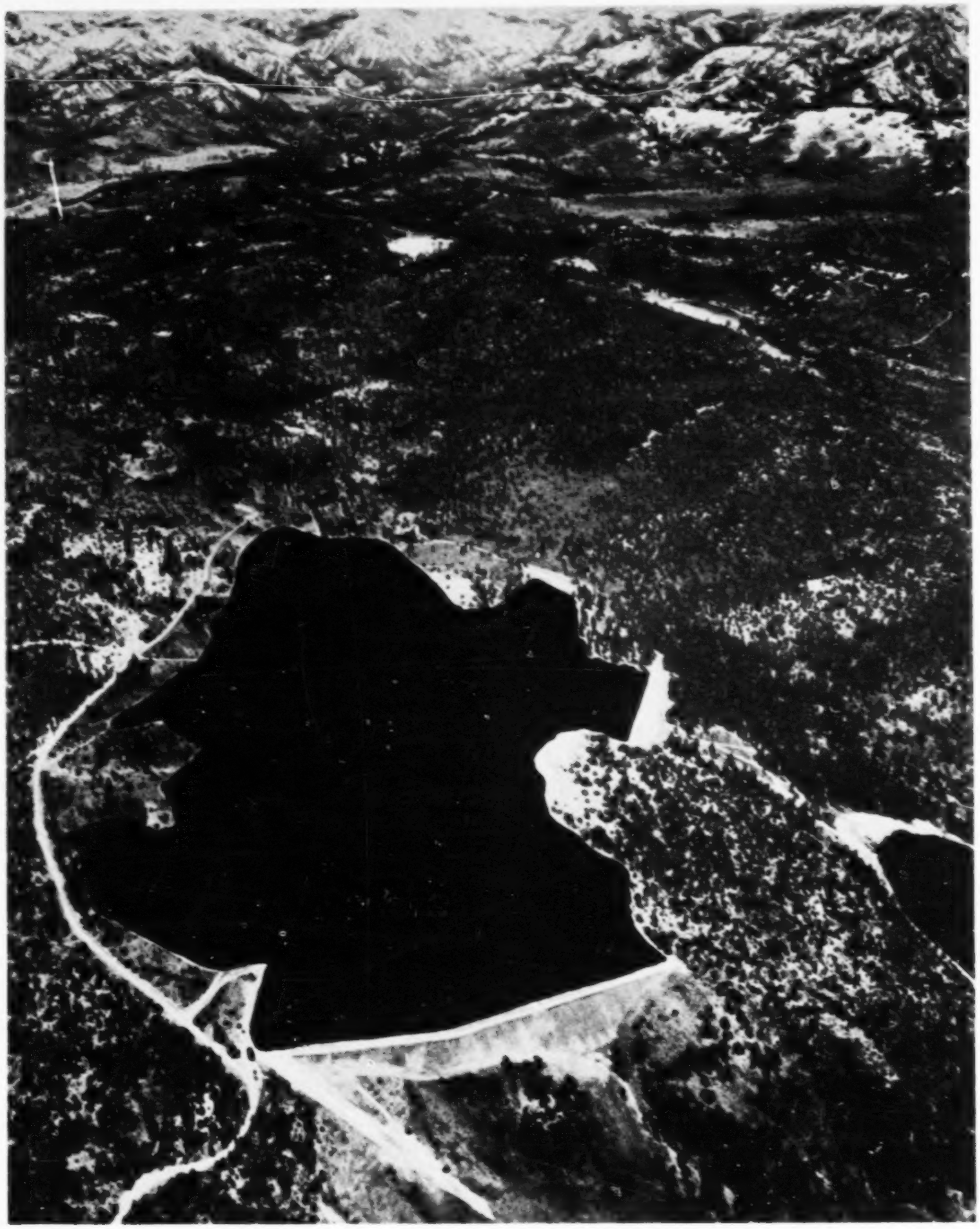

Figure 89

AERIAL VIEW OF INDIAN CREEK RESERVOIR

project receives.

The second phase, sampling and testing under this grant, was aimed principally at getting information which would allow an evaluation of the safety and suitability of water in the Reservoir for irrigation and recreation uses.

The objectives of the study by the LTAC were: to determine the effects of the reclaimed water on biological, physical, and chemical characteristics of the Reservoir; to relate these characteristics of the Reservoir water to the nutrient concentrations of the influent water; to evaluate the relative effects of biostimulants to the treated water and those added by exchange from the underlying soils and sediments; and finally to attempt to correlate the data on actual algal growth obtained from Reservoir studies with laboratory and pilot plant growth potential tests of the reclaimed water. The results of the LTAC study are reported completely in "Eutrophication of Surface Waters - Indian Creek Reservoir", First Progress Report (FWQA Grant No. 16010 DNY), May 1970, Lake Tahoe Area Council, South Lake Tahoe, California, and will not be duplicated herein, but only drawn upon as necessary to complete this report.

Visual Observations. Prior to filling Indian Creek Reservoir with reclaimed water, there was, of course, a great deal of speculation about what would happen when it was filled. Engineers and others connected with the project had collected bottles and jugs of pilot plant effluent which had been exposed to sunlight for several months on window ledges or desks and which had shown no signs of algal growth. Also, plastic drums had been filled with various dilutions of Lake Tahoe water and tertiary effluent and little if any growth was detected. The favorable results of these crude batch tests did not necessarily mean that there would be no nuisance blooms of algae in the Reservoir, where dynamic rather than static conditions prevailed. Some engineers and other visitors were predicting that the Reservoir would quickly become a "green slimy mess", principally on the basis that no nitrogen removal was being practiced in the treatment plant during most of the initial filling period and ammonia nitrogen concentrations generally exceeded 15 mg/l. Fortunately, these prophesies of doom did not come true, and no objectionable growths of algae have occurred.

The Reservoir was subject to very close scrutiny not only by project personnel but any an almost continuous parade of visitors including laymen, conservationists, politicians, engineers, and others from many fields of endeavor. The water has always been quite clear. Objects can be perceived on the bottom of the Lake at depths of 3 to 19 feet. There never has been any odor from the water in the Reservoir. The color varies from a dark blue under the best conditions, to a light blue under most conditions, to a very light green for very short times immediately following the runoff of snow melt into the Lake. Most of the algae which grow appear to be single-cell greens and they are present in very small numbers. Strings, clumps, or mats of algae have not been seen in the Lake.

Immediately adjacent to Indian Creek Reservoir there is another lake, Stevens Lake, which receives only natural runoff from the Indian Creek watershed. Indian Creek Reservoir always presents as good an appearance as Stevens Lake does.

During the first year or two of the project color photographs were taken of the Reservoir (water's edge at dam and shoreline, and general overall view) at different seasons in order to compile a record of the true condition of the lake at all times.

Physical and Chemical Tests. In Appendix B a daily record is given of flows entering and leaving Indian Creek Reservoir. The general plan of Reservoir operation is to fill it in winter and spring, and to draw it down for irrigation of pasture lands during summer and fall. At spillway level the Reservoir contains about one billion gallons of water, the maximum water depth is 56 feet, and the surface area is 160 acres. At minimum pool or conservation level the Reservoir contains about one-third billion gallons, has a maximum depth of 40 feet, and a surface area of about 95 acres. The Reservoir has now been filled completely and drained down to recreation pool level twice and is in the process of being filled for the third time. At this time, it is believed that the leaching of nutrients from the topsoil beneath the Reservoir has decreased substantially over that originally taking place and that the effects on water quality probably are now negligible.

In 1968, samples of reservoir water were collected on a more or less regular schedule from late June through early December. The results of the laboratory analyses are shown in Table 51 .

Snow and ice conditions made the Reservoir inaccessible from December 1968 to March 28, 1969 when the Lake was reached by snowmobile.

The water along the reservoir shore was extremely clear. Table 52 shows the laboratory analysis of a grab sample collected at the water and dam interface. Ice conditions on the reservoir surface prevented collection of off-shore samples.

TABLE 51

EFFLUENT STORAGE RESERVOIR
LABORATORY ANALYSES - 1968

			Alkalinity (mg/l as $CaCO_3$)					
Date	DO mg/l	pH	HCO_3	CO_3	Total	Temp.	NO_3N mg/l	P mg/l
6/28	6.5	8.3	23	32	55			
7/10	7.2	8.1	143	4	147			
7/17	11.0	8.7	119	52	171			
7/24	7.9	8.9	95	62	157			
8/14	5.6	8.3	162	14	176			
8/21	7.3	8.4	170	14	184			0.40
8/28	10.7	8.2	145	38	183			
9/4	11.0	8.5	108	58	166			
9/24	9.0	8.0	166	24	190			
10/1	8.5	8.1	190	20	210			
10/9	12.3	8.1	192	20	212	14°C	3.6	0.003
10/23	8.9	8.2	200	20	220			
10/30	9.4	8.1	185	30	215	12°C	2.65	
11/7	8.3	8.3	165	34	199	9°C		
11/26	10.7	8.3	147	44	191	6°C		0.18
12/12		8.5			182	2°C		0.114

Approximately 1/2 billion gallons of water was impounded on this date.

Table 52

Effluent Storage Reservoir-Laboratory Analyses
March 28, 1969

Dissolved Oxygen	10.2 mg/l
pH	7.2
Total Alkalinity	82 mg/l as $CaCO_3$
Temperature	42°F
Nitrite	0.04 mg/l as N
Nitrate	0.67 mg/l as N
Ammonia	2.1 mg/l as N
Phosphorus	0.04 mg/l as P

Temperature and dissolved oxygen profiles of the Reservoir on August 1 and September 16, 1969 are shown in Table 53.

Data from Stevens Lake and Indian Creek Reservoir are shown in Table 54. Stevens Lake is located in the adjacent watershed to the reservoir and has been used as a control for the data collection program. The lake was constructed for irrigation storage about 20-30 years ago and is well established to the run off conditions of the area.

On October 28, 1969, dissolved oxygen and temperature profiles were performed at the reservoir. Dissolved oxygen ranged from 7- 9 mg/l and temperatures from 47 to 49°F.

In January 1970 a Hinde Air-Aqua System was installed in Indian Creek Reservoir. This system consists of ten 1/2 hp air compressors and ten sections of perforated aeration tubing each about 250 feet located in the central deep-water part of the Lake just upstream from the dam. Each compressor has a capacity of about 3 cfm of air. The principal purpose of this aeration, turnover system is to prevent the formation of complete ice cover over the Reservoir surface. It also can be used to prevent or correct thermal or oxygen stratification in the Lake water. The system has been very effective and its operation has been simple and trouble-free. When the equipment arrived the Reservoir was completely covered with ice which ranged in thickness from 6 to 12 inches. Holes were chopped in the ice to install the air tubing. Eight of the compressors were operated at one time, and within four or five days a major portion of the ice had been melted due to the action of the turnover system in circulating warm

TABLE 53

TEMPERATURE AND DISSOLVED OXYGEN PROFILES OF INDIAN CREEK RESERVOIR[4]

August 1, 1969

Station	Temp. °F 1	Temp. °F 2	Temp. °F 3	Dissolved Oxygen mg/l 1	Dissolved Oxygen mg/l 2	Dissolved Oxygen mg/l 3
Depth (ft.)						
Surface	72	74	73	8	8	8
3.3	72	73	73			
6.6	71	72	72			
9.9	70	71	72		7	
13.0	70	71	71			
16.4	67	67	69	5	7	7
18.0		67			1	
19.7	66		66			
23.0	66		66	2		
26.2	65		65			
27.0			65	1		1
33.2	65					
39.4	64					
44.3	63			1		

September 16, 1969

Station	Temp. °F A	Temp. °F B	Temp. °F C	Dissolved Oxygen mg/l A	Dissolved Oxygen mg/l B	Dissolved Oxygen mg/l C
Surface	64	64	63		6	6
5	63	64	63	6		
10	63	63	63			
15	63	63	63			
17			62			6
20	65	63		6	5.5	
25	64	63				
30	64	63				
35	64	62				
38		62			5	
40	64					
45	64			5		

(1) 44.3 ft. A. 45 ft. (depth of reservoir at sampling station)
(2) 18.0 ft. B. 38 ft.
(3) 27.9 ft. C. 17 ft.
(4) Courtesy California Department of Fish & Game.

TABLE 54

WATER QUALITY OF INDIAN CREEK RESERVOIR AND STEVENS LAKE - 1969(1)

	Indian Creek Reservoir			Stevens Lake	
Sample Dates	7/16	8/7	9/16	7/16(2)	8/7
Volume (acre-ft.)	2400	2380	2050		
Surface Temp.(° F)	70	68	63	73°	70°
Color (filtered)	17	15	25	10	10
Turbidity (SJU)	11	7	10	10	5
Secci Disk Depth (ft.)	7.5	7.3	4		10.8
D.O. mg/l @ 5' below surface	5.8	6.2	4.7	6.9	6.6
Chlorine, mg/l	0	0	0		
pH	7.8	7.5	7.4	8.7	9.2
Alkalinity as $CaCO_3$					
phenolphthalein mg/l	0	0	0	12	13
methyl orange mg/l	105	116	116	43	43
PO_4 -P mg/l	.05	.07	.08	.015	.02
NH_3 -N mg/l	3.4	2.4	4.3	.3	0
NO_2 -N mg/l		.25	.36		0
NO_3 -N mg/l	1.9	1.7	1.1	0	.8
MBAS, mg/l	0.11	.06	.01	0	.04

(1) Courtesy California Department of Fish and Game

(2) All samples taken at 5 ft. depth, except 7/16 samples at Stevens Lake which were taken at 2 ft. depth

water from the deep part of the Lake to the surface under the ice. In 1971 the intermittent use of the aeration system has successfully prevented development of complete ice cover. Ice which forms around the edges of the Lake can be quickly melted by use of the system. This assists in maintaining the dissolved oxygen levels necessary to support the trout fishery.

On January 5, 1970, the Hinde Air-Aqua System was put in operation at the reservoir to melt the layer of ice and keep the surface free of ice. The next day dissolved oxygen and temperature profiles indicated the reservoir was near saturation with no stratification. Dissolved oxygen and temperatures ranged from 8-11 mg/l and 40-44°F, respectively. The ice cover was very clear and the near saturation values were probably attributable to a combination of natural photosynthesis and mechanical aeration.

On March 12, 1970, dissolved oxygen and temperature profiles ranged from 13-15 mg/l and 40-43°F, respectively.

In June 1970, the project quarterly report read as follows:

"The expanded 7.5 mgd water reclamation plant has now for 2-1/2 years continuously produced reclaimed water of very high quality, exceeding the stringent export requirements."

"On numerous occasions the orthophosphate content of the reclaimed water was measured at values in the range of 0.002 to 0.005 mg/l as phosphorus, which approaches the quality of Lake Tahoe water in this respect. At the start of plant operations two years ago, residual phosphorus content to less than 0.01 mg/l has been accomplished through several minor but important changes in plant operating procedures, without any increase in the amount of chemicals used in treatment of the wastewater."

"The clarity of the one billion gallons of water reclaimed by our plant which is now stored in Indian Creek Reservoir is excellent. An 8-inch white Secchi disc can be seen at depths of 3 to 19 feet in the Lake. This improvement in clarity of the water in the Reservoir probably is due to two factors. First is the fact that the initial filling of the Reservoir has been virtually complete for several weeks now, and nutrients are no longer being leached by the water from topsoil which was inundated for the first time. The second factor is that removing one algal nutrient, phosphorus, from the reclaimed water to a satisfactory level has restricted algal growth in the Reservoir. The success of this means for control of algae, by phosphorus removal, is in accordance with predictions of the effectiveness of this method made by the District's Consulting Engineers in their preliminary reports on the project several years ago. The judgement of the Consultants that the growth of algae could be controlled by phosphorus removal alone, and without the need for complete nitrogen removal is also borne out to date by field observations and laboratory examination of Reservoir water quality."

"Trout fishing in Indian Creek Reservoir has been excellent. During the first two days of the season which opened May 2, State Fish and Game official, Robert Tharratt, reported that 920 anglers landed more than 1,250 rainbow-cutthroat trout which averaged over 12 inches in length and one pound in weight. The Lake was stocked last summer with 38,000 trout ranging in size from fingerlings to sub-catchables. An additional 92,000 trout have been planted in 1970, to bring the total trout planted to 100,000. The largest recorded catch to date was a 3-1/4 pound, 19 inch trout."

The October 1970 quarterly report includes the following:

"The recent report, 'Eutrophication of Surface Waters-Indian Creek Reservoir', as prepared and published by the Lake Tahoe Area Council, contains what we consider to be a very significant finding by Dr. P. H. McGauhey and his colleagues. This is the fact that an unanticipated 75 percent ammonia removal is taking place in the Reservoir. The ammonia nitrogen content of reclaimed water entering the Reservoir is about 15 mg/l while that of the water in the Reservoir is now 3 mg/l (nitrates=1 to 3 mg/l, nitrites=less than 0.1 mg/l). The ammonia nitrogen content of the raw wastewater averages about 30 mg/l, so that overall combined removal of ammonia by the plant and Reservoir is 90 percent. Apparently the ammonia in the influent water to the Lake is being converted first to nitrate and then to nitrogen gas (which escapes harmlessly from the Reservoir to the atmosphere) by the organisms in the benthic deposits in the Reservoir through bacterial nitrification-denitrification processes. This is confirmed by nitrogen inventories of the lake environment. To date this means of nitrogen removal in the Reservoir appears to be more reliable and economical than any known plant process designed for this purpose. It is this phenomenon which has made it possible for the trout fishery to be established in the Lake. It appears that the continuing study of the biology of Indian Creek Reservoir now in progress by the Lake Tahoe Area Council may well lead to better understanding of the principles involved in nitrogen removal and their more widespread practical use in wastewater reclamation."

Ordinarily upon conversion of the ammonia to nitrate in the Lake water, algae could be expected to assimilate the nitrate nitrogen and incorporate it in cell growth, thus interrupting the nitrogen cycle at this point and preventing the conversion of nitrate to nitrogen gas. One explanation which is advanced to explain the fact that the nitrogen cycle proceeds in Indian

Creek Reservoir is the very low phosphorus content of the water. This phosphorus shortage appears to limit algal growth and allows the nitrogen cycle to proceed without serious interference through action of benthic organisms to production of free nitrogen gas (rather than algae) from the nitrates. The nitrogen gas then escapes harmlessly to the atmosphere.

Another explanation offered is that there is direct release of ammonia gas at the Reservoir surface. However, because of the low pH of the Lake water this does not appear to be a significant nitrogen loss mechanism.

Irrigation. About 2 billion gallons of water has been withdrawn during three summers of Reservoir operation for irrigation of pasture, hay, and alfalfa. The availability of this water for irrigation was especially valuable in 1968, which was a very dry year. Three cuttings of alfalfa were obtained where only one could have been harvested without the use of the reclaimed water.

Rainbow Trout Fishery. One of the hallmarks of public acceptance of the reclaimed water and acknowledgement of its high quality was the opening of the trout fishing season on May 2, 1970. The fishing in Indian Creek Reservoir was established by the California Department of Fish and Game through the enthusiastic cooperation of Robert Tharratt and his co-workers. See Figure 90.

The July/August, 1970 issue of "Outdoor California" carries a story by Mr. Tharratt about the "Exciting New Era" of trout fishing in the "pioneering wastewater reclamation lake". Excerpts from this account follow:

"The opening of the 1970 trout season may well have marked the beginning of an exciting new era for California fishermen and recreationists. About 900 trout anglers were on hand to try their luck in California's newest 'fishing hole', Indian Creek Reservoir, and they were not disappointed. By sundown Sunday of opening weekend more than 1,200 trout averaging 13 inches long and more than one pound each had been creeled by the lucky anglers."

"Born out of the Lake Tahoe water controversy, this 160-acre Alpine County lake represents the ultimate in the concept of water reutilization and provides a prime example of environmental enhancement through man's technology."

"Indian Creek Reservoir, situated in the eastern foothills of the Sierra Nevada in Diamond Valley near Markleeville, is the culmination of a

Figure 90

RAINBOW TROUT FROM INDIAN CREEK RESERVOIR

NOT REPRODUCIBLE

10-year program of the South Tahoe Public Utility District to preserve the clarity of Lake Tahoe."

"The lake water is reclaimed waste water produced by a tertiary treatment process in one of the world's most advanced waste treatment plants on Tahoe's south shore. Following treatment, the water is transported through 27 miles of buried 18-inch to 24-inch pipeline, including a lift of nearly 1,300 feet over 7,700-foot Luther Pass to the reservoir site on Indian Creek."

"The Lake Tahoe pollution control effort began in 1960 when the South Tahoe Public Utility District began operating a conventional secondary treatment plant. The effluent was sprayed on Forest Service and private lands in the basin. While solving the immediate problem of waste treatment, it did not guarantee the higher goal of preventing nutrient enrichment of the lake, which might stimulate algae growth and thus impair for all time the clarity of one of the world's most beautiful fresh water lakes."

"A program was initiated by the utility district in 1961 to improve the waste treatment process. This work led to the development of advanced wastewater treatment processes which were incorporated into the plant in 1965. Further additions to the treatment process were added, and the plant was expanded to a total capacity of 7.5 million gallons a day by 1968."

"While the plant expansion was underway, local, state, and federal regulatory agencies and political entities involved made the decision that the only completely safe way to protect Lake Tahoe within existing technology was to export all sewage and solid wastes out of the Tahoe Basin."

"Work was initiated on the export system. The pipeline was laid from the plant to the reservoir site in Alpine County, a pumping station was built at Luther Pass, and a dam and reservoir were constructed on a small tributary at Indian Creek. The water reclamation plant was completed and in operation in 1968."

"The effluent water of the Tahoe plant is of very high quality and is generally indistinguishable from water occurring naturally in other lakes. Although it meets Public Health Service standards for drinking water, recycled water is not now used for domestic purposes but is used only for recreation and irrigation. The high quality of the water is evidenced by the fact that rainbow trout are thriving."

"The first trout were planted by the Department of Fish and Game in October 1968, but none survived the winter. Apparently the heavy and prolonged winter ice cover led to a series of conditions whereby the lake's oxygen supply was depleted, and the fish suffocated. Additional fish tests were made in 1969 by the DFG, and when it was determined the water was satisfactory for trout, the DFG planted 8,000 fingerlings in August."

"A 'preview of coming attractions' was evident in October 1969 when DFG netting revealed that the four-inch fingerlings planted 75 days before were nine inches long!"

"Even more startling was the growth of the smaller fingerlings planted by a DFG airplane at the same time. These rainbow-cutthroat trout hybrids were air dropped at a size more than 400 fish to the pound. When sampled in October, these fish were six inches long and had increased in weight 40 times, averaging nearly two ounces each!"

"Things looked bright indeed for the fishing at Indian Creek, but the winter loomed ahead. Could the fish survive the winter?"

"Technology once again came to the fore. The South Tahoe Public Utility District, at the suggestion of the Department of Fish and Game, agreed to install an aeration system in the reservoir to provide oxygen during the freeze-over and to hasten the breakup of ice once it had formed."

"The plan included the onshore installation of an engine-driven compressor system and a series of weighted plastic hoses laid on the reservoir bottom. In operation the system would deliver compressed air over the bottom of the lake, providing oxygen for the fish and causing a gradual circulation of water."

"Water is heaviest at 39 degrees F, and hence a frozen lake is "warmer" on the bottom than at the surface just under the ice. The circulation of this warm bottom layer to the surface tends to help melt the ice."

"Indian Creek Reservoir froze over completely near the end of December before the air hoses were installed. It was necessary to break holes in the ice to get the aeration lines in place. The pumps were turned on the first week in January, and within 24 hours the small holes cut in the four-inch thick ice had enlarged to several feet in diameter."

"Several fish were observed jumping at rising air bubbles, and chemical tests throughout the lake revealed that oxygen was plentiful in all areas. The aeration system was doing the job. With continued pumping and a coincidental break in the weather, the lake was entirely free of ice in less than two weeks and stayed that way the rest of the winter."

"Nets were set in the lake in March 1970 to see if the trout had survived. Fat, scrappy rainbow trout to nearly a foot in length attested to the success of the operation."

"What about the future?"

"Indian Creek owes its success to the fine cooperation among federal, state, and local agencies. The California Water Commission recently approved recreation grants of $180,000 under the Davis-Grunsky program, administered by the Department of Water Resources for part of the construction cost of the reservoir project and for the construction of initial water supply and sanitary facilities for the recreation area."

"The Bureau of Land Management, which administers the project lands, is seeking funds to build and operate the recreational complex consisting of a campground, picnic area, and boat launching ramp."

"Alpine County plans to construct a new road to the nearby county airport, which will improve access to the lake. All of the above facilities should be in operation within two or three years."

"The South Tahoe Public Utility District and its consultants, Clair A. Hill and Associates, have provided assistance in many ways, including project planning, water monitoring, and the aeration system."

"Add to this the planned interim stocking of approximately 30,000 trout annually by the Department of Fish and Game, and the future does indeed look bright for the California sportsman."

Results of the Lake Tahoe Area Council Study. The LTAC report one "Eutrophication of Surface Waters - Indian Creek Reservoir", First Progress Report (FWQA Grant No. 16010 DNY), May 1970, in Chapter VI, Summary and Conclusions, contains 37 conclusions and observations which are reproduced here for the convenience of the reader. For the detailed data on which these conclusions and observations are drawn, the reader is referred to the Report.

"1. The water impounded in Indian Creek Reservoir during 1969 was approximately 20 percent surface runoff and 80 percent reclaimed water. Consequently its quality was more influenced by reclaimed water than by surface runoff.

2. Because the drainage area above the reservoir is small (1700 acres) it may be expected that as the volume of exported water increases,

the quality of impounded water will increasingly be influenced by reclaimed water.

3. Estimates of runoff and evaporation rates previously reported to the STPUD by its engineering consultants appear to be sufficiently valid to permit a reasonable water budget estimate for Indian Creek Reservoir.

4. Year round observations designed to establish more accurate runoff and evaporation rates should be made in order to refine the limnological knowledge of the reservoir as it matures.

5. Infiltration rates of mid-1969 were of the order of 0.035± ft of water per day, a value which is reasonable.

6. The clarity of Indian Creek Reservoir water during the period of observation was typical of shallow impoundments of relatively good quality water. During the period June 1969 through March 1970 it varied from 0.84 to 3.46 meters (Secchi disk). In April 1970 it was as great as 6 meters.

7. Water temperatures in the upper stratum of the reservoir, where light and other environmental factors are most favorable to plankton growth, reach an 18°-22°C range also favorable to biological activity. In winter they fall below the lower limit for biological activity.

8. With only minor exceptions, the observed data on physical characteristics of the reservoir are in line with typical and explainable phenomena, although not in sufficient detail to permit statistical evaluations.

9. The importance of wind movement in describing and evaluating the limnology at Indian Creek Reservoir is such that a more detailed and continous observation of wind director and velocity should be a part of any continued surveillance of the reservoir.

10. Chemical analyses of impounded and discharge water show that there was little difference in conservative chemical quality from top to bottom. Dissolved oxygen declined with depth in July as did alkalinity (carbon source) and ammonia (nutrient source).

11. COD in reservoir water was not demonstrably related to VSS or any other of the parameters evaluated.

12. There is good evidence that iron in Indian Creek Reservoir

played an important role in the life cycle of biota which appeared in the surface stratum of the impounded water.

13. pH is a sensitive parameter of the limnological characteristics of Indian Creek Reservoir, however, it varied in impounded water only from 7.7 to 8.5 as compared to 7.4 to 8.8 in the influent reclaimed water.

14. In terms of conductivity and chemical components the water impounded at Indian Creek Reservoir is of good quality for irrigation water.

15. Differences in concentration of conservative quality factors such as chloride and calcium in influent and impounded water in Indian Creek Reservoir were clearly the result of dilution.

16. Substantial evidence was found that bicarbonate alkalinity was used as a source of carbon by the biota of Indian Creek Reservoir during the period of study.

17. Prior to September 1969 the impounded water was poorly mixed and the oxygen profile reached zero at the bottom level.

18. The reservoir became well mixed in September 1969. Thereafter results of horizontal and vertical distribution of oxygen indicated that a single observation at one sampling station was a sufficient basis for computing the oxygen resource of the impounded water mass.

19. The impounded water was quite homogeneous during the period of study. Consequently only the dissolved oxygen concentration in the water mass was particularly changed by mixing of the reservoir.

20. It is not yet known whether poor mixing was a seasonal phenomenon or an aspect of a new limnologically immature impoundment. Continued observation of the reservoir during another season should answer this question and so make possible predictions of water quality in the reservoir.

21. Phosphorus was considered the limiting nutrient in reservoir waters. N/P ratios of influent reclaimed water were of the order of 150/1. In the impounded water the ratio remained above 29/1 during the period of study.

22. With but little aid from dilution the NH_3-N concentration changed from 15 mg/l in the influent water to some 4 mg/l in the impounded water. Evidence is submitted to show that the reduction was almost certainly due to nitrification-denitrification rather than growth of biomass.

23. Influent reclaimed water exported to Indian Creek Reservoir proved toxic to trout in field tests, and to algae in laboratory assays. Nevertheless, trout planted in the reservoir after October 1968 showed no effects. Ammonia concentration in the reclaimed water was the presumed toxic material.

24. A benthic invertebrate survey by the FWQA in October 1969 showed an average of 464 dipterous larvae per square foot in the 17 areas sampled. These were all essentially of three species of low-oxygen tolerant types, although a previous condition of low oxygen in the bottom stratum of water was overcome as early as September 1969.

25. Although the benthic invertebrate survey showed a high yield of biota, the diversity of biota was unusually limited. The same was observed in Indian Creek itself just below the discharge of Indian Creek Reservoir.

26. There is evidence that although the water mass was severely phosphorus limited, benthic organisms made use of phosphorus in the soil underlying the reservoir.

27. In the impounded water rainbow trout flourished at an NH_3-N level of about 4 mg/l, although 2 mg/l is often considered a maximum for such species. Trout planted in Indian Creek Reservoir in August 1969 increased in length from 1.7 to 6 in., and from 4.5 to 8.9 in., in length by October 1969.

28. Bioassays of impounded water showed limited growth, probably because of unfavorable N/P ratios, although a seasonal pattern of a readily explainable nature was evident.

29. Essentially no growth occurred in laboratory bioassays of undiluted reclaimed water, indicating the presence of some toxic material. When diluted to one percent concentration with Lake Tahoe water the toxic effect was overcome to the extent that algal growth proceeded.

30. From plankton samples taken over a period of time it is evident that a varied plankton population indicative of good productivity had developed in Indian Creek Reservoir by July 1969.

31. A plankton survey of impounded waters and bottom muds made in April 1970 showed a species distribution characteristic of impounded water. However, the reservoir appeared to be a highly productive body of water.

32. The plankton survey showed Indian Creek near the reservoir dam to have a biota characteristic of an enriched water.

33. Monitoring of Indian Creek Reservoir, including benthic surveys, should be continued to reveal any changes which may result from:

a. greater removals of nitrogen at the STPUD water reclamation plant.

b. greater releases of impounded water during the summer season.

c. reduction in soil phosphorus as a source of phosphorus.

34. Observation of Indian Creek over a period of time may make it possible to design water reclamation processes capable of producing a water of balanced quality suited to a broad spectrum of recreational uses yet not subject to algal blooms.

35. A major finding of the study is that by simple impoundment of the water exported from the Tahoe Basin, its quality was changed from that untenable to fish and certain algae, to one of good productivity of both, within the limits of available nutrients.

36. In evaluating the results of the study it should be borne in mind that the nitrogen content of the exported water did not represent the ultimate degree of removal to be expected in water reclamation by the STPUD, and that Indian Creek Reservoir may be expected to undergo further changes in the process of maturing.

37. Waste water reclamation at South Tahoe has progressed to the point where under normal circumstances water would not be exported. However, because Lake Tahoe is more unique than normal Indian Creek Reservoir provides a good proving ground outside the Tahoe Basin in which to evaluate the processes and develop the scientific knowledge needed to permit its future use within the Basin if desired."

Recreational Use. As previously mentioned, the Lahontan Regional Water Quality Control Board has formally approved and authorized use of Indian Creek Reservoir for "unrestricted recreational purposes" including fishing, boating, water skiing, swimming, and other water contact sports. This approval was granted only after 9 months of observation of plant performance, water testing, and observation of the Reservoir, and after consultation and receipt of recommendations from other state agencies including the California Department of Health.

Figure 91

SAILBOATING ON INDIAN CREEK RESERVOIR

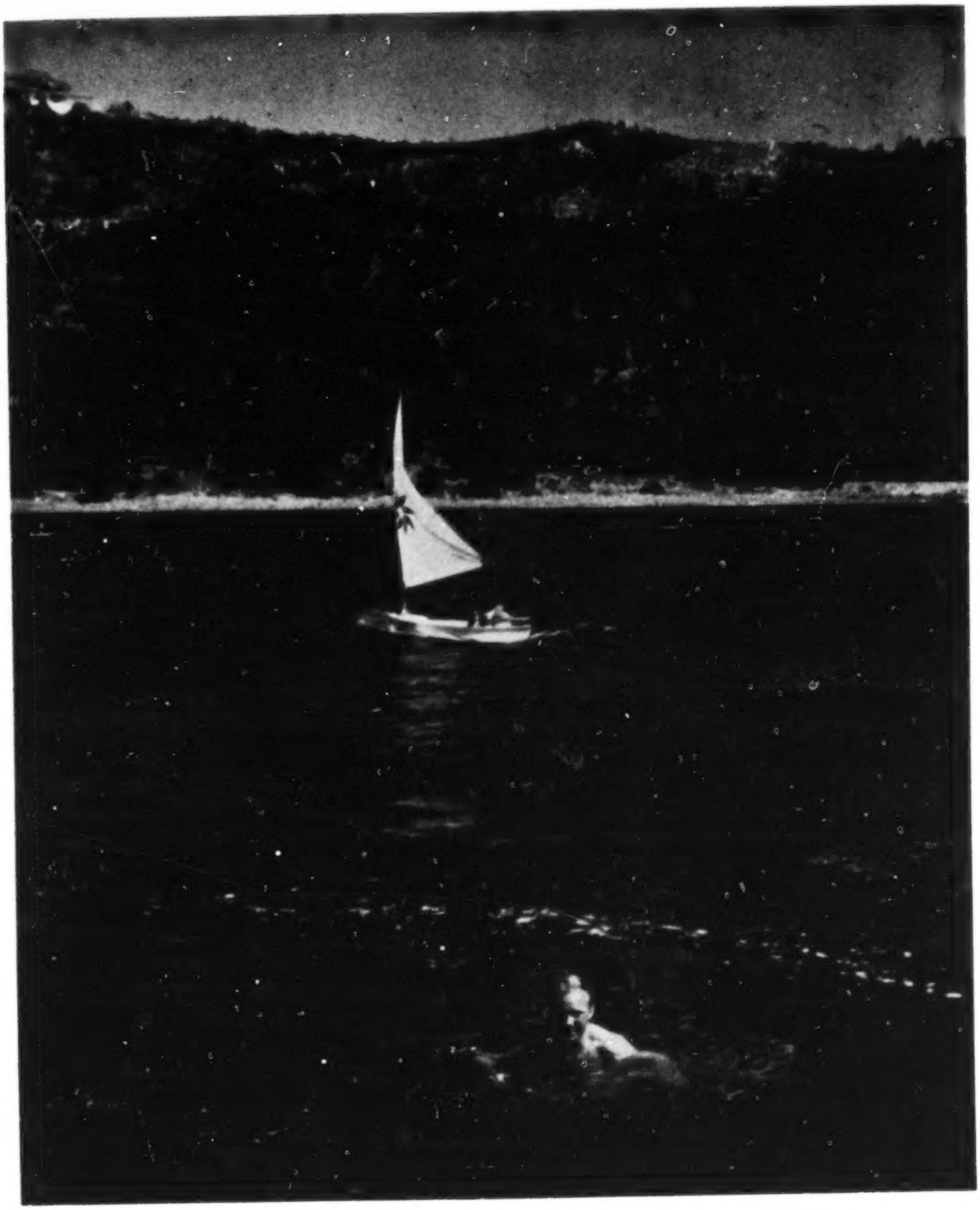

Figure 92

SWIMMING IN INDIAN CREEK RESERVOIR

SECTION XXV

CAPITAL AND OPERATING COSTS FOR CONVENTIONAL AND ADVANCED WASTE TREATMENT

Introduction. The increasing interest by the general public in the quality of the environment has stimulated several questions concerning water pollution abatement. One of the most significant questions is what the cost of cleaning up our nation's lakes and rivers will be. In some instances, the addition of secondary treatment will be sufficient to reduce the problem; however, in other areas one or more of the various advanced waste treatment processes will be required to eliminate a pollution problem. A knowledge of the costs for the various degrees of conventional and advanced waste treatment is essential in planning the nation's water pollution abatement needs.

The purpose of this section is to present in detail the actual costs of conventional and advanced waste treatment and to briefly review the benefits of the plant scale conventional-advanced waste treatment scheme used continuously since 1968 at South Lake Tahoe.

This section will show that the total cost at 7.5 mgd was $166/mg for conventional waste treatment and $217/mg for advanced waste treatment. These costs are based on producing the extremely high quality reclaimed water described in earlier sections with 100 percent reliability. Lesser requirements should demonstrate lower costs. Thus at South Lake Tahoe, the cost of advanced waste treatment is approximately 30 percent greater than the cost of conventional treatment.

The conventional and advanced waste treatment phases, with the exception of the ammonia stripping tower, are designed for 7.5 mgd. The ammonia stripping tower design capacity is 3.75 mgd.

Conventional treatment includes primary clarification, and both plug flow and completely mixed activated sludge secondary treatment. The activated sludge process is operated with a high organic loading and low mixed liquor suspended solids and sludge age, to prevent nitrification and to keep the majority of the nitrogen in the ammonium ion form. The mixed liquor is chlorinated at 2 mg/l before clarification if nitrifying organisms begin to proliferate. Raw and waste activated sludges are dewatered in centrifugals and then incinerated.

Advanced waste treatment begins with phosphorus removal and clarification of the secondary effluent, using lime. The spent lime mud is thickened in a gravity thickener, dewatered by centrifuging, and then recalcined in a multiple hearth furnace for reuse. Phosphorus rich lime mud is classified in the centrifugal and wasted to the organic sludge system.

The effluent from the lime clarifier flows through an ammonia stripping tower to a two-stage recarbonation system. Scrubbed stack gases from the lime recalcining and sludge incineration furnaces are used to neutralize the high pH water. The recarbonated effluent then is pumped to mixed media filters and carbon columns. Two ballast ponds, each one million gallons in capacity, float on the system in order to provide flow equalization and supplemental filter backwash water. Spent carbon is withdrawn periodically from the carbon columns, thermally reactivated in a separate multiple hearth furnace, and then returned to the carbon columns. The carbon column effluent is dosed with 2 mg/l of chlorine and then lifted 1,500 feet and through 27 miles to Indian Creek Reservoir in Alpine County, California.

Assumption for Capital Costs. The capital costs include all equipment and construction costs. They do not include design costs. The equipment and construction costs were taken from District records of actual contracts awarded for the various treatment phases. These contracts were completed at various periods between 1960 and 1968. The EPA Sewage Treatment Plant Construction Cost Index, Base Year 1957-1959=100, was used to adjust the capital costs to 1969. It was assumed that the San Francisco Region Indexes were equivalent to South Lake Tahoe. All costs were adjusted to 1969 San Francisco Index and then to the National Average Index for 1969. The 1969 Index values used were 136.2 for San Francisco and 127.1 for the Nation. The 1969 replacement costs per million gallons were based on the national average at 7.5 mgd design capacity assuming capital amortization of all the costs at 5 percent for 25 years and no federal assistance. In fact, the capital costs to the District were much lower since federal grants from the USPHS, EDA, and EPA financed approximately 46 percent of the total construction cost for conventional and advanced waste treatment.

Capital Costs. The capital costs are shown in Table 55 and also later in the operational cost tables. Included in the capital cost figures for a specific treatment phase are items common to several processes.

TABLE 55

SOUTH TAHOE PUBLIC UTILITY DISTRICT, CALIFORNIA
CAPITAL COSTS FOR CONVENTIONAL AND ADVANCED WASTE TREATMENT PLANT 7.5 MGD DESIGN CAPACITY

Treatment Phase	Actual Contract Total Construction Cost Per Phase [2]	Estimated National Average Replacement Construction Cost for 1969	Estimated Replacement Costs Per MG for 1969
CONVENTIONAL TREATMENT			
Primary	$ 692,000	$ 753,000	$ 19.50
Activated Sludge	1,247,000	1,300,000	33.60
Organic Sludge [5]	583,000	545,000	14.10
Chlorination	9,000	11,000	0.30
TOTAL, Conventional Treatment	$2,531,000	$2,609,000	$ 67.50
ADVANCED TREATMENT			
Nutrient Removal			
Phosphorus Removal			
Lime Treatment	401,000	378,000	9.70
Lime Recalcining [6]	552,000	516,000	13.50
SUBTOTAL, Phosphorus Removal	$ 953,000	$ 894,000	$ 23.20
Nitrogen Removal [7]	327,000	310,000	8.00
Recarbonation	162,000	152,000	4.00
SUBTOTAL, Nutrient Removal	$1,442,000	$1,356,000	$ 35.20
Filtration	705,000	687,000	17.80
Carbon Treatment			
Carbon Adsorption [8]	656,000	632,000	16.30
Carbon Regeneration	193,000	199,000	5.20
SUBTOTAL, Carbon Treatment	$ 849,000	$ 831,000	$ 21.50
TOTAL, Advanced Treatment	$2,996,000	$2,874,000	$ 74.50
TOTAL WATER RECLAMATION			
Conventional Treatment	2,531,000	2,609,000	67.50
Advanced Treatment	2,996,000	2,874,000	74.50
TOTAL, WATER RECLAMATION	$5,527,000	$5,483,000	$142.00

[2] Construction costs are taken from District records of actual contracts awarded for various phases. Contracts for construction were completed at various periods between 1960 and 1968. These costs have not been adjusted to a common year.

[5] Includes sludge handling, dewatering, incineration, and ash disposal.

[6] Includes lime mud handling, dewatering, and recalcining.

[7] Ammonia stripping.

[8] Includes initial carbon costs to fill all carbon columns.

These items include buildings, electrical systems, piping, and controls not specifically identifiable in the construction contracts. Both area and volume relationships are used to proportion this capital cost to specific treatment phases.

Total capital costs, based on 1969 national average replacement costs, were 67.50 $/mg for conventional treatment and 74.50 $/mg for advanced treatment. The 20 acre site where the present conventional and advanced waste treatment processes are located was acquired in conjunction with the construction of the original 2.5 mgd primary and secondary plant in 1960. Since the records did not show the site acquisition as a separate item, the cost of the 20 acres was included only in the capital cost of conventional treatment.

Assumptions for Operating Costs. The operating costs included in this section are based on the plant design capacity of 7.5 mgd from February 1969 to December 1970. During this period, the actual average monthly influent flows varied between 1.79 mgd and 3.15 mgd. As a result of recycling water from scrubber flows, backwashing filters, and backflowing carbon columns, the filtration and carbon adsorption flows during the same period varied between 3.13 mgd and 5.22 mgd.

To compare operating costs on the common basis of the plant design capacity, it was assumed the total cost for fuel, chemicals, make-up lime, and make-up carbon would increase in proportion to the flow. However, the same assumption could not be made for electricity, operating and maintenance labor costs, equipment repair, and instrument maintenance. Costs per day for electricity were adjusted upward to reflect the equipment characteristics at 7.5 mgd. The cost per day for operating and maintenance labor, repair materials, and instrument maintenance were assumed to be the same as at present and design flows.

The assumption that the plant is staffed as though it were operating at design capacity was made for the following reasons. During the grant, three individuals were required per shift to operate the plant. One operator spent approximately five hours in the laboratory analyzing samples for the District's FWQA research grant, and three hours performing plant related duties. The second operator spent an hour per shift measuring flows and keeping track of expendables for the grant, and seven hours in plant operation. The third individual controlled the operations within the incineration building, which did not vary with flow. This extensive data collection would not be taking place at 7.5 mgd nor would it be the usual practice at other advanced waste treatment plants. Maintenance labor and repair materials would be affected by equipment age but not necessarily by flow since most of the equipment is running today. Because it was the basic purpose of this section to show costs at 7.5 mgd in 1969 and 1970, age was not considered to be a factor.

It was assumed, however, that emphasis placed on each treatment phase by the first two operators would be different during carbon regeneration periods when this additional phase must be covered.

No District operating and capital costs associated with sewers, pump stations, janitorial work in administrative areas, minor plant modifications, effluent export, FWQA research grant, and general Utility District administration were included. It is felt that these costs were not typical operating costs for actual waste treatment.

Operating Cost Data Collection and Analysis. Each month the computer provided machine listings of the individual operating costs per treatment phase for current and design plant flows. The computer also determined and printed the average to date costs for the current and design flows.

The monthly labor rates for the operations and maintenance included the actual monies paid by the District to or in behalf of the individual for straighttime, overtime, standbytime, holidays, vacation, sick leave, premium pay, Social Security, retirement fund, medical insurance, unemployment tax, and Workmen's Compensation. The labor rates represented all monies paid divided by the actual hours worked.

Two methods were used to allocate labor costs to the various treatment phases. For maintenance labor, the actual hours spent within a specific treatment phase were fed into the computer. Overhead time, such as supervision, lunch, coffee breaks and unreported time, was prorated among the various treatment phases on the basis of actual hours reported. The maintenance group included six individuals.

Operating labor was divided among the various treatment phases by fixed percentages. Three shifts were used, seven days per week. The basic shift included three operators. A total of 15 operators were needed to cover the three shifts, chief operator, and vacation and sick leave makeup. The fixed percentages used to allocate the operational labor hours are shown in Table 56. The fixed percentages were based on personal interviews with each of the operators, and on observations by the authors and the District administrative staff. Again, these percentages were stored in the computer as variable constants.

TABLE 56

PERCENT OPERATIONAL LABOR DIVISION PER TREATMENT PHASE

Treatment Phase	Without Carbon Regeneration	During Carbon Regeneration
PLANT EXCLUDING INCINERATION BUILDING - 2 Operators/Shift		
Primary Treatment	20.80	13.53
Secondary Treatment	25.00	17.70
Lime Clarification	4.17	.83
Ammonia Stripping	2.10	.42
Recarbonation	2.08	.83
Filtration	6.25	4.17
Carbon Adsorption	6.25	4.17
Carbon Regeneration		25.00
INCINERATION BUILDING - 1 Operator/Shift		
Organic Sludge Dewatering	6.25	6.25
Organic Sludge Incineration	4.17	4.17
Lime Mud Dewatering	4.17	4.17
Lime Mud Recalcining	12.50	12.50
Lime Clarification (Slakers)	4.17	4.17
Recarbonation (CO_2 Compressors)	2.09	2.09
TOTAL	100.00	100.00

Operator responsibilities include process monitoring and adjustments, chemical mixing, routine equipment servicing, and inside cleanup.

Electrical costs were divided among the treatment phases on the basis of ampere-hours per month. The actual running time for each electrical motor was one of the inputs for each month. The amperes for each motor were stored in the computer as variable constants.

Cubic feet of natural gas used by the sludge incinerator, lime recalciner and carbon furnace and the amounts of chemicals used each month were each measured separately.

Instruments were maintained by an outside contract. The costs per treatment phase were determined by the number of instruments repaired or calibrated per treatment phase. The contract included labor, parts, and instrument replacement.

Repair material costs included replacement costs, material, repair equipment purchase, and rental costs. This category also reflected outside labor cost, as well as material costs for work done outside the plant, such as rewinding electric motors.

Unit Operating Costs. Costs of all commodities at Lake Tahoe are high in comparison to the average of commodity costs in the USA. This is due in large measure to the location in a mountainous area and to the Tahoe area's tourist-based economy. In order to permit comparison with costs which might be anticipated in other areas, Table 57 has been prepared to show the present cost of various commodities at Lake Tahoe. These unit costs were stored in the computer as variable constants.

Primary Treatment. Raw sewage entering the plant passes through a barminutor, a parshall flume and then into the primary clarifier. A rectangular 2.7 mgd clarifier equipped with water spray scum collection and a 4.8 mgd, 100 foot diameter circular clarifier with mechanical scum collection can be used. The underflow is degritted with a cyclone degritter.

Table 58 shows the operating and capital costs for primary treatment. The barminutor, primary clarifier, degritter, and sludge and scum withdrawal pumps were considered to be part of primary treatment.

Secondary Treatment. The primary effluent flows by gravity to the activated sludge secondary treatment system. This system consists of three plug flow aeration basins (0.9 mgd each), two completely mixed aeration basins (2.4 mgd each) all in parallel, and two circular secondary clarifiers, 2.0 and 5.5 mgd, respectively. Activated sludge is wasted to

TABLE 57

UNIT COSTS(1) 1969 AND 1970

Labor (2)	
Operations	$ 6.11 /hour
Maintenance	5.05 /hour
Electricity(3)	12.10/1,000 kwh
Fuel (4)	0.0543/therm
Make-up Lime (Quicklime)(5)	28.83/ton CaO
Chemicals	
Chlorine	114.00/ton
Polymer - Sludge Dewatering	2.53/lb
Polymer - Lime Coagulation	1.92/lb
Polymer - Filtration	1.92/lb
Alum - Filtration (Liquid)(6)	0.014/lb
Activated Carbon Make-up(7)	0.305/lb

(1) All appropriate unit costs are f.o.b. South Lake Tahoe and include a 5% California sales tax.

(2) Labor costs include all direct and indirect monies paid upon the employees behalf. The rates are averages for 1969 and 1970.

(3) Includes energy and demand charges.

(4) Natural gas at about 860 BTU/cu ft at 6,200 feet elevation and billed on the basis of interruptable service.

(5) Average calcium oxide content 93.6%.

(6) Liquid alum weight 11.08 lbs/gal. Dry alum equivalent 49%.

(7) Activated carbon at 30 lbs/cu ft.

TABLE 58

OPERATING AND CAPITAL COSTS
PRIMARY TREATMENT AT 7.5 MGD

OPERATING COSTS	$/Day
Electricity	4.99
Operating Labor	80.38
Maintenance Labor	6.61
Repair Materials	3.24
Instrument Maintenance	1.43
Total Operating Cost	96.65

TOTAL COSTS PER MG	$/MG
Operating	12.89
Capital	19.50
Total	32.39

the primary clarifier.

The average secondary effluent concentrations were 70 mg/l of COD, 25 mg/l of BOD and 25 mg/l of Suspended Solids. Total efficiency of the primary and secondary treatment phases for COD, BOD, and Suspended Solids were 65, 85, and 90 percent, respectively.

The aeration basins, blowers, mechanical mixers, secondary clarifiers, and sludge return pumps were included in secondary treatment. Table 59 presents the operating and capital costs.

Organic Sludge Dewatering. Raw and waste activated sludges are pumped through a cyclone degritter at 1 to 2 percent solids to a holding tank. From the holding tank the sludges are then pumped to one or two 24 by 60 inch solid bowl centrifugals for dewatering to about 18% solids. A polymer is used in conjunction with centrifuging. The second centrifugal may also be used for dewatering lime mud; or as has been the practice since February 1970, this second machine may be used to dewater the phosphate rich lime centrate coming from the lead lime mud centrifugal. In this later mode, the low calcium, high phosphate cake coming from the second centrifugal is combined with cake from the organic centrifugal and carried by belt conveyor to a multi-hearth incinerator.

Table 60 shows the cost of dewatering organic sludge. The sludge holding tank, centrifugal feed pumps, organic sludge centrifugal (s), polymer feed system, and sludge conveyor belts were considered to be part of sludge dewatering costs. Maintenance labor and repair costs primarily reflect the cost of periodically cleaning the sludge holding tank, and repairing the sludge feed pumps and organic centrifugal (s).

Organic Sludge Incineration and Disposal. Dewatered organic solids and waste lime are incinerated in 14.3 foot diameter, six hearth furnace at 1500°F. The maximum furnace capacity is about 10.5 tons of dry solids per day. Ash from the furnace is conveyed by bucket elevator and screw conveyor to a hopper located outside the incineration building. To date, ash (organic and waste lime) has been produced at the rate of 30.7 ft^3 per million gallons of plant influent.

Table 61 shows the operating cost for organic sludge incineration and disposal. The incineration and ash conveying systems were considered to be the organic sludge incineration system. The costs include the expense of drying the waste lime mud and its disposal. The dumping charges at the disposal site, 3 miles from the plant, were not included.

TABLE 59

OPERATING AND CAPITAL COSTS
SECONDARY TREATMENT AT 7.5 MGD

OPERATING COSTS	$/Day
Electricity	125.99
Operating Labor	101.90
Maintenance Labor	8.10
Repair Materials	5.85
Instrument Maintenance	4.75
Chlorine	6.04
Total Operating Cost	252.63

TOTAL COSTS PER MG	$/MG
Operating	33.68
Capital	33.60
Total	67.28

TABLE 60

OPERATING COSTS
ORGANIC SLUDGE DEWATERING AT 7.5 MGD

ORGANIC SLUDGE DEWATERING	$/Day
Electricity	16.26
Polymer	138.47
Operating Labor	32.18
Maintenance Labor	22.27
Repair Materials	19.61
Instrument Maintenance	.78
Total Operating Cost	229.57

TOTAL OPERATING COST	
Per MG Plant Influent	$ 30.61 /MG
Per Ton of Dry Solids Dewatered	$ 23.24 /Ton

TABLE 61

OPERATING COSTS
ORGANIC SLUDGE INCINERATION AT 7.5 MGD

ORGANIC SLUDGE INCINERATION	$/day
Electricity	5.63
Natural Gas	97.11
Operating Labor	21.47
Maintenance Labor	6.20
Repair Materials	1.84
Instrument Maintenance	2.58
Ash Disposal	
Labor	2.47
Trucking(1)	.82
Total Operating Cost	138.12

TOTAL OPERATING COST	
Per MG Plant Influent	$ 18.41 /MG
Per Ton of Dry Solids Dewatered	$ 13.98 /ton

(1) Based on hourly truck rate during loading, 2 way hauling, and dumping. Dumping charges at disposal site not included. Hourly trucking charges included 5 yr amortization of capital cost for 5 ton dump truck plus 5% of capital for maintenance.

Overall Costs - Organic Sludge Dewatering, Incineration, and Disposal. The operating and capital costs shown in Table 62 represent the total cost for organic sludge handling and disposal excluding dumping charges.

Lime Coagulation. Chemical coagulation (with lime) of the secondary effluent to pH 11 is accomplished with a rapid-mix flocculation basin, followed by a 100 foot diameter conventional clarifier. To reach pH 11 for the South Lake Tahoe wastewater, a lime dose of 300 mg/l of calcium oxide is required. A polymer, at a 0.1 to 0.3 mg/l dose, is added just as the water leaves the flocculation chamber to improve clarification.

The lime coagulation system typically removes 95 percent of the phosphorus it receives. In the clarifier effluent, phosphorus concentrations range between 0.2 and 0.7 mg/l PO_4-P and turbidity levels between 1 and 10 SJU.

Table 63 shows the specific operating and capital costs for this treatment phase. The lime storage bins, slakers, floc basin, clarifier, polymer feed system, and sludge draw-off pumps were considered to be part of the lime coagulation system. As shown in Table 56, operating labor from both the general plant and the incineration building were charged to lime clarification. Maintenance labor and repair material costs for 1969 and 1970 represented primarily costs associated with the slakers, lime buildup on the flash mixer, sludge removal from the lime mixing basin, and cleaning of the lime slurry line from the slakers to the flash mixing basin.

Lime Mud Dewatering. Lime mud is pumped from the chemical clarifier and reaction basin to a gravity thickener for solids concentrations. In turn, the thickened mud is pumped by either of two variable speed pump units to a 24-inch x 60-inch solid bowl centrifugal for dewatering. Phosphorus is wasted from the system in the form of calcium hydroxyapatite by operating the lime centrifugal so that 10-30 percent of the solids entering the machine come out in the centrate. A second centrifugal clarifies the centrate and the phosphorus-rich cake is conveyed to the organic sludge furnace.

Operating and capital costs for the dewatering phase of lime recalcination are shown in Table 64 . The items of equipment included in this phase were the thickener, lime sludge pumps to the centrifugal, the centrifugal itself and lime cake conveyor to the furance. In 1969 and 1970, most of the maintenance labor and repair costs were related to lime mud line cleaning and centrifugal repair. The dewatering costs also included the second centrifugal when it was being used to dewater lime centrate for

TABLE 62

OPERATING AND CAPITAL COSTS

ORGANIC SLUDGE DEWATERING AND INCINERATION AT 7.5 MGD

ORGANIC SLUDGE DEWATERING	\$/MG(1)	\$/TON(2)
Operating Costs	30.61	23.24
Capital Costs	4.81	3.65
Total Costs	35.42	26.89
ORGANIC SLUDGE INCINERATION		
Operating Costs	18.41	13.98
Capital Costs	9.29	7.05
Total Costs	27.70	21.03
TOTAL OPERATING AND CAPITAL COSTS	63.12	47.92

(1) Per MG of plant influent
(2) Per ton of dry solids dewatered

TABLE 63

OPERATING AND CAPITAL COSTS
LIME COAGULATION AT 7.5 MGD

OPERATING COSTS	$/DAY
Electricity	5.22
Make-up Lime	168.19
Polymer	22.18
Operating Labor	30.67
Maintenance Labor	9.59
Repair Materials	3.14
Instrument Maintenance	3.04
Total Operating Cost	242.03

TOTAL COSTS PER MG	$ / MG
Operating	32.27
Capital	9.70
Total	41.97

TABLE 64

OPERATING COSTS

LIME MUD DEWATERING AT 7.5 MGD

LIME MUD DEWATERING	$/DAY
Electricity	8.92
Operating Labor	21.47
Maintenance Labor	16.04
Repair Materials	8.81
Instrument Maintenance	0.00
Total Operating Cost	55.24

TOTAL OPERATING COST	
Per MG Plant Influent	$ 7.37/MG
Per ton CaO Recalcined	5.49/ton CaO

the lead centrifugal.

The costs for drying and disposing of the dewatered high phosphate lime mud were included in the costs for organic sludge incineration and ash disposal.

Lime Mud Recalcining. Dewatered lime mud is conveyed from the centrifugal to a 14.3 foot diameter, six hearth furnace for recalcining at 1800-1900°F. The maximum capacity of the furnace is about 20 tons of dry solids per day. The recalcined lime exits by gravity through a crusher into a thermal disc cooler, and then is pneumatically conveyed to the recalcined lime storage bin for eventual reuse.

For the purpose of determining operating and capital costs, all equipment and functions from the lime furnace to the lime storage bin were considered to be part of the lime recalcining system. These costs are shown in Table 65. The majority of the maintenance costs were associated with the conveying of recalcined lime from the furnace to the storage bin.

Overall Costs - Lime Dewatering and Recalcining. The operating and capital costs shown in Table 66 represent both dewatering and recalcining costs. If lime mud dewatering costs are considered common to any lime clarification process, then the costs of lime recalcining are competitive with buying new lime, particularly when disposal costs are included. At South Lake Tahoe new lime was purchased at $28.83/ton CaO, whereas lime recalcination cost $31.61/ton CaO.

Nitrogen Removal by Ammonia Stripping. Following lime clarification, ammonia stripping is utilized at South Lake Tahoe to remove the nutrient nitrogen from the wastewater. The stripping process includes two constant speed pumps, a cross flow cooling tower with a two-speed reversible 24-foot fan, a concrete collection basin below the tower, and a flow measurement weir on the basin exit. The tower has an average design air-to-water ratio of 250 cu ft/gal, and a nominal capacity of 3.75 mgd.

Tower removal efficiencies have varied from 30 to 90 percent, depending on air temperature and extent of calcium carbonate buildup on the fill before cleaning. During the winter when the air temperature is lower than 32°F (0°C.), the tower is bypassed to prevent ice buildup on the fill. Tower influent NH_3-N concentrations have ranged from 15 to 30 mg/l, with effluent values from 3 to 15 mg/l.

TABLE 65

OPERATING COSTS
LIME MUD RECALCINING AT 7.5 MGD

LIME MUD RECALCINING	$/DAY
Electricity	6.55
Natural Gas	142.83
Operating Labor	64.36
Maintenance Labor	12.68
Repair Materials	8.31
Instrument Maintenance	3.63
Total Operating Cost	238.36

TOTAL OPERATING COST	
Per MG Plant Influent	$ 31.78 MG
Per Ton CaO Recalcined	23.70/ton CaO

TABLE 66

OPERATING AND CAPITAL COST
LIME MUD DEWATERING AND RECALCINING AT 7.5 MGD

LIME MUD DEWATERING	$/MG	$/Ton CaO
Operating Costs	7.37	5.49
Capital Costs	2.90	2.16
Total	10.27	7.65
LIME MUD RECALCINING		
Operating Cost	31.78	23.70
Capital Cost	10.60	7.91
Total	42.38	31.61
TOTAL OPERATING AND CAPITAL COSTS	52.65	39.26

The operating and capital costs of nitrogen removal for both intermittent and continuous operation are listed in Tables 67 and 68, respectively. Operating labor included backflushing of tower pumps and cleaning the distribution deck to remove $CaCO_3$ precipitation, routine chart changing, process inspection, lubrication, and daily determination of tower ammonia removal efficiency. Maintenance costs, to date, reflect the costs of removing calcium carbonate scale from the influent pumps and tower fill.

pH Adjustment by Recarbonation. The next unit in the liquid processing stream is the two-stage recarbonation of the ammonia stripping tower effluent. The system, located beneath the ammonia stripping tower, is divided into three sections: first-stage recarbonation, a reaction basin, and second-stage recarbonation. In the first-stage basin compressed scrubbed stack gases from the lime recalcining and sludge incineration systems are used to reduce the pH from 11.0 to 9.6, the minimum solubility of $CaCO_3$. Approximately 17 percent additional $CaCO_3$ can be settled out in the reaction basin with the dual-stage system. This additional removal also decreases deposition of $CaCO_3$ in the ballast ponds and on the filter media and activated carbon. The second-stage reduces the pH from 9.6 to 6.8-7.5, also with scrubbed stack gases.

Operating and capital costs for two-stage recarbonation are shown in Table 69. The costs included the CO_2 compressor system, first- and second-stage recarbonation, and the reaction basin with its sludge collection system. Operator time included pH control associated with compressor gas flow, servicing the compressors, and removal of lime sludge from the reaction basin. The maintenance costs principally reflected compressor repair costs.

Mixed Media Filtration. The secondary recarbonation effluent is pumped to the mixed media filters at about 5 gpm/sq ft. There are three pairs of mixed media beds which operate in parallel. Each pair of beds comprises a unit, and the two beds are operated in series during all three operational cycles; that is, during filtration, backwash, and filter-to-waste. Normal operation of the beds (or filters) is controlled automatically from a control panel. The filter medium is a special patented (Neptune MicroFLOC, Inc.) coarse-to-fine medium containing coal, sand, and garnet. Alum is applied to the filter influent at 10 to 30 mg/l to obtain the desired turbidity in the finished water. Polyelectrolyte (or secondary flocculant) may be added as a filter aid to control floc breakthrough.

After a predetermined time or throughput, each pair of beds is automatically taken off line (one pair at a time in sequence), backwashed, and

TABLE 67

ACTUAL OPERATING AND CAPITAL COST AMMONIA STRIPPING AT 7.5 MGD UNDER INTERMITTENT CONDITIONS(1)

OPERATING COSTS PER DAY	$/Day
Electricity(1)	41.12
Operating Labor	4.63
Maintenance Labor	5.17
Repair Material	.78
Instrument Maintenance	.94
Total Operating Cost	52.64

TOTAL COST PER MG	$/ MG
Operating	7.02
Capital	8.00
Total	15.02

(1) Intermittent conditions due to air temperatures below 32° F at which the tower freezes. Only electricity is affected.

TABLE 68

OPERATING COSTS FOR AMMONIA STRIPPING AT 7.5 MGD FOR CONTINUOUS OPERATION

OPERATING COST PER DAY	$/Day
Electricity(1)	60.78
Operating Labor	4.63
Maintenance Labor	5.17
Repair Material	.78
Instrument Maintenance	.94
Total Operating Costs	72.30

TOTAL COST PER MG	$/MG
Operating	9.64
Capital	8.00
Total	17.64

(1) Average cost per day at 7.5 mgd from months of continuous operation, i.e., May through September 1969, and 1970.

TABLE 69

OPERATING AND CAPITAL COSTS
RECARBONATION AT 7.5 MGD

OPERATING COSTS PER DAY	$/Day
Electricity	12.15
Operating Labor	16.87
Maintenance Labor	7.14
Repair Materials	3.11
Instrument Maintenance	.65
Total Operating Costs(1)	39.92

TOTAL COST PER MG	$/MG
Operating	5.32
Capital	4.00
Total	9.32

(1) Stack gases from lime recalciner and/or sludge incinerator supply the CO_2.

returned to service. The beds are backwashed at 15 gpm/sq ft with filter influent water. The filtration cycle, depending on the influent water, may last from 15 to 60 hours.

The contribution of the filters towards improving the final plant effluent can be shown by the following values. Phosphorus concentrations in the filter effluent average 0.1 mg/l with removal efficiencies of 50 to 99 percent. Effluent concentration for suspended solids average less than one mg/l and for turbidity about 0.5 Standard Jackson Units.

The major contribution, however, can only be seen through practical plant operating experience. Both the filters and the carbon adsorption columns, for the past 3 years, 24 hours a day, have enabled this plant to produce an extremely high quality effluent despite complete activated sludge failures and minor chemical clarification problems.

The operating and capital costs for filtration are shown in Table 70. These costs include pumping the recarbonated effluent against a static head of about 100 feet, surface and backwash pumps, separation beds, and chemical feed. The high pumping head results from site location, filter headloss, and carbon column headloss. Since the average valves of headless across the filters and carbon columns are about the same, 50 percent of the pumping costs have been assigned to each of these two functions.

Operating labor included manually initiating filter backwashes, periodic monitoring of the filtration and backwash cycles, general cleaning, and equipment servicing. Maintenance costs for 1969 and 1970 included rewinding electric motors on two influent pumps, an inspection of the mixed media beds, repair of the surface wash arms and minor automatic valve work.

Carbon Adsorption. Activated carbon adsorption follows mixed media filtration. The activated carbon system includes eight steel columns, each containing 22-25 tons of 8 x 30 mesh granular activated carbon. The separation bed effluent flows under pressure upflow through the columns.

Chemical oxygen demand concentration in the separation bed effluent averaged 20 mg/l with approximately 50 percent removal across the activated carbon. MBAS concentrations in the separation bed effluent averaged 0.6 mg/l, and the carbon column effluent concentration was about 0.1 mg/l. Biochemical Oxygen Demand (BOD) concentrations in the separation bed effluent ranged from 3 to 6 mg/l, and carbon column effluent concentrations ranged from 1 to 3 mg/l. Color removals across the

TABLE 70

OPERATING AND CAPITAL COSTS
FILTRATION AT 7.5 MGD

OPERATING COSTS PER DAY	$/Day
Electricity	47.34
Chemicals - Alum/Polymer[1]	73.66
Operating Labor	24.53
Maintenance Labor	9.83
Repair Materials	3.32
Instrument Maintenance	10.67
Total Operating Costs	169.35

TOTAL COST PER MG	$/MG
Operating[2]	22.58
Capital	17.80
Total	40.38

(1) Insignificant amount of polymer used

(2) Total operating cost per MG of water filtered would be 18.25 MG. Includes 7.5 mgd plant influent, plus recycle streams.

carbon averaged 50 percent, with a range of 10-15 units on the influent and 4-7 units on the effluent.

Operating and capital costs for activated carbon adsorption are shown in Table 71.

Operational labor included flow monitoring, sampling, and backflowing of columns. Maintenance included instrumentation calibration, corrosion inspection of the interior of the columns, and repair of appurtenances. As mentioned in the filtration section, 50 percent of the pumping costs, including maintenance for pumping through the filters and carbon columns were assigned to the carbon adsorption system.

The initial carbon charge for the carbon columns was included in the capital cost.

Carbon Regeneration. After an average dosage of 207 pounds of carbon per million gallons has passed through the columns, a batch of 3 tons was withdrawn from each column for regeneration in sequence. From past experience, this dosage appears to give optimum usage of the carbon but is high enough to prevent a COD, MBAS, or color wavefront breakthrough.

Spent carbon is regenerated at 1,650° to 1,750°F in a multiple hearth furnace. The furnace can be operated at feed rates of 100 to 6,000 lbs per day. After regeneration, the activated carbon is returned to the columns. Carbon losses used for the cost analysis averaged 8.9 percent.

Operating and capital costs for activated carbon regeneration are shown in Tables 72 and 73. As shown in Table 73, the total combined operating and capital cost of carbon regeneration is about 10 cents per lb of carbon regenerated.

Electricity included power used for instrumentation, driving rabble arms, and fans for shaft cooling, induced draft, and combustion air. Natural gas and make-up carbon are self-explanatory. Operational labor included furnace operation, defining, transferring spent and regenerated carbon, and regeneration efficiency analysis. Maintenance labor and repair material were for the furnace, instrumentation, and carbon transfer appurtenances. Maintenance costs for 1969 and 1970 included furnace startup and shutdown every 4 to 8 weeks, cleaning carbon dewatering and defining screens, carbon slurry pumps and stack-gas scrubber. The extensive maintenance of furnace startup and shutdown would be eliminated if regeneration were continuous.

TABLE 71

OPERATING AND CAPITAL COSTS CARBON ADSORPTION AT 7.5 MGD

OPERATING COSTS PER DAY	$/Day
Electricity	47.34
Operating Labor	24.53
Maintenance Labor	3.27
Repair Material	1.15
Instrument Maintenance	4.24
Total Operating Cost	80.53

TOTAL COST PER MG	$/MG
Operating(1)	10.74
Capital(2)	16.30
Total	27.04

(1) Total operating cost per MG of water treated would be 8.77/MG. This figure includes 7.5 mgd plant influent, plus recycle streams.

(2) Includes initial carbon charge.

TABLE 72

OPERATING AND CAPITAL COSTS
CARBON REGENERATION AT 7.5 MGD

OPERATING COST PER DAY	$/Day
Electricity	2.23
Natural Gas	6.15
Make-up Carbon	70.39
Operating Labor	91.90
Maintenance Labor	16.21
Repair Material	1.17
Instrument Maintenance	1.90
Total Operating Cost	189.95

TOTAL COST PER MG	$/MG
Operating (1)	25.33
Capital	5.20
Total	30.53

(1) Total operating cost per MG of water treated would be 19.28/MG. This figure includes 7.5 mgd plant influent, plus recycle flows.

TABLE 73

OPERATING AND CAPITAL COST OF CARBON REGENERATION PER TON OF CARBON REGENERATED

OPERATING COST PER TON	$/Ton
Electricity	1.73
Natural Gas	4.72
Make-up Carbon	53.98
Operating Labor	68.74
Maintenance Labor	39.52
Repair Material	2.36
Instrument Maintenance	1.43
Total Operating Cost	172.48

TOTAL COST PER TON	$/Ton
Operating	172.48
Capital	29.76
Total	202.24

Disinfection by Chlorine. The quality of water from advanced waste treatment has a major effect on chlorine disinfection and the amounts needed. Since the chlorine demand of the District's final effluent is very low, instantaneous chlorine values of 2-3 ppm insured complete disinfection. Gaseous chlorine is added to the final effluent as it is pumped to the main export pump station at Luther Pass.

The District must maintain high coliform count (MPN/100 ml) standards. Over the period covered by this grant, the median has always been less than 2.0 and there have been no consecutive samples above 23.

In 1969, nine sets of water samples were collected and submitted to' the FWPCA laboratory in Cincinnati for virus examination. Although viruses were found in the secondary effluent, all nine tests of the reclaimed water after chlorination were negative for virus. No virus has been recovered from the water being exported to Indian Creek Reservoir in two summers of sampling. While this does not necessarily mean that the water is free of virus, at least all of the results to date are favorable.

The operating costs from February 1969 to December 1970 at 7.5 mgd were $2.72/MG and the capital cost was $0.30/MG. These costs are included in this section as part of the conventional waste treatment costs.

Summary. At the time the water reclamation plant was designed, very little experience was available to aid in estimating full-scale plant efficiencies. Approvals of the plant design by the various regulatory agencies also included stringent export requirements on the plant effluent quality. For the 3 year period covered by this grant the plant effluent was continuously well below the export requirements.

All of the reclaimed water has been exported to Indian Creek Reservoir. The man-made lake has been approved by local and state regulatory agencies for all water contact sports. The reservoir supports a thriving population of rainbow trout and a state grant has been awarded for construction of recreational facilities. The water in the reservoir is sparkling clear, and Secci disc observations have been recorded as high as 20 feet. The low level of phosphorus in the plant effluent appears to be giving adequate control of algal growth. During the irrigation season, a portion of the water in the reservoir is released for irrigation of forage crops by the ranches below the reservoir.

The benefits of advanced waste treatment in a water-short area or where it is essential to conserve the ecology of an area far outweigh the costs of advanced waste treatment.

A summary of the costs required to meet state effluent or export standards and to produce the reclaimed water of exceptionally high quality are shown in Tables 74 and 75 and 76. Several miscellaneous items were not included in the preceding operating cost categories. Table 77 lists these items and their related costs.

A very valuable water resource for recreation, irrigation, and perhaps some day for direct reuse has been produced at an additional cost of $217/MG which is approximately 30 percent greater than for conventional treatment. Furthermore, the costs do not reflect the benefits of actual federal assistance or resale of the product water. If the assumption is made that the average sewage flow per person is 110 gpd, the total cost for tertiary waste treatment per person per month is about 75 cents. Put another way, the cost of tertiary waste treatment adds less than $9.00 per person per year to the total cost of waste collection and treatment.

Increase in Construction Costs at South Lake Tahoe. The South Tahoe Public Utility District pays an above normal price for construction of improvements due to the geographical and climatological conditions of the Lake Tahoe Basin. Construction costs in the basin are 15% to 30% higher than costs in the nearest industrialized areas which are 50 to 100 miles away. The higher costs are primarily a result of the remote location, climate and altitude, and a correspondingly short construction season.

As a result of the remote location, the majority of the labor force must be imported. Subsistence of 9.50 to 11.50 per man-day is required by union contracts. Since the cost of living is higher in the basin, supervisory and semi-permanent personnel are paid an additional rate for the increased cost of living. The resulting total labor cost may be as much as 40% higher than less remote areas. Also since the workmen are away from home, they are more likely to engage in the gambling and night life readily available at the lake, which results in lower working efficiency. Shipping costs are much higher because all highway mountain passes are above 7100 feet elevation. The remote location also decreases the availability of construction materials. Concrete delivered to the project site costs approximately double of that of less isolated areas. At times there is an extended downtime of men and equipment while waiting for parts and materials.

TABLE 74

TOTAL OPERATING COSTS
CONVENTIONAL WASTEWATER TREATMENT AT 7.5 MGD

OPERATING COSTS	$/Day
Electricity	152.87
Natural Gas	97.11
Chemicals - Polymers	138.47
Chlorine	23.58
Operating Labor	235.93
Maintenance Labor	46.38
Repair Materials	31.75
Instrument Maintenance	11.30
Total Cost per Day	737.39

TOTAL OPERATING COST	$/MG
Per MG Plant Influent	98.32

TABLE 75

TOTAL OPERATING COSTS
ADVANCED WASTEWATER TREATMENT AT 7.5 MGD

OPERATING COSTS	$/Day
Electricity(1)	170.87
Natural Gas	148.98
Chemicals (Alum and Polymer)	95.84
Make-up Lime	168.19
Make-up Carbon	70.39
Operating Labor	278.96
Maintenance Labor	79.93
Repair Materials	29.79
Instrument Maintenance	25.07
Total Cost Per Day	1,068.02

TOTAL COST PER MG	$/MG
Total Cost per MG Plant Influent	142.40

(1) Based on intermittent weather conditions for ammonia stripping. If NH_3 stripping operated continuously, total electricity would have been $190.53/day.

TABLE 76

TOTAL OPERATING AND CAPITAL COSTS FOR CONVENTIONAL AND ADVANCED WASTE TREATMENT AT THE SOUTH TAHOE WATER RECLAMATION PLANT FOR THE 7.5 MGD DESIGN CAPACITY IN 1969 and 1970

	$/MG
CONVENTIONAL WASTE TREATMENT(1)	
Operating Costs	98.32
Capital Costs	67.50
Total	165.82
ADVANCED WASTE TREATMENT	
Operating Costs	142.40
Capital Costs	74.50
Total	216.90
MISCELLANEOUS OPERATING COSTS	11.57
TOTAL OPERATING AND CAPITAL COST	394.29

(1) Includes chlorination costs of final effluent and disposal phosphorus rich lime mud.

TABLE 77

MISCELLANEOUS OPERATING COSTS FOR CONVENTIONAL AND ADVANCED TREATMENT

Item	$/Day	$/MG at 7.5 MGD
Uniforms	10.97	1.46
Laboratory Supplies	8.22	1.10
Fire Insurance	41.10	5.48
Telephones	6.85	.91
Standby Propane	2.74	.37
Miscellaneous Supplies	10.97	1.46
Plant Grounds-Cleanup	5.90	.79
TOTAL	86.75	11.57

The alpine climate and 6300 foot elevation of the area results in a favorable construction season of only six months in length, usually May through October. The contractor must mobilize and demobilize his operations each year, which requires extensive overtime. In order to retain key personnel, the contractor must finance construction retentions through the unproductive winter months. The quality of the work force may be lessened because normally better workmen work in areas with longer construction seasons and less severe climates. The heavy snow load requires stronger permanent and temporary construction buildings. The inclement weather reduces equipment and labor production and efficiency.

In Table 78 the actual construction and equipment costs for the 7.5 mgd capacity water reclamation plant are listed, and manifest the increased construction costs as a result of the unique geographical and climatological situation of the Lake Tahoe Basin.

TABLE 78

ACTUAL CONSTRUCTION AND EQUIPMENT COSTS AT THE 7.5 MGD SOUTH LAKE TAHOE WATER RECLAMATION PLANT BY CONTRACT COMPLETION DATES

CONVENTIONAL TREATMENT - COST		
Primary Treatment		
	1960	$ 430,000
	1968	262,000
		$ 692,000
Secondary Treatment		
	1960	$ 508,500
	1965	56,500
	1968	682,000
		$1,247,000
Organic Sludge (Handling, dewatering, incineration and ash disposal)		
	1968	583,000
Chlorination		
	1960	8,000
	1968	1,000
		$ 9,000

ADVANCED TREATMENT - COST		
Lime Treatment		
	1965	$ 800
	1968	400,200
		$ 401,000
Lime Recalcining (dewatering and recalcining)		
	1968	552.000
Nitrogen Stripping		
	1968	327,000
Recarbonation		
	1968	162,000
Filtration		
	1965	267,000
	1966	72,000
	1968	366,000
		$ 705,000
Carbon Adsorption		
	1965	159,000
	1968	497,000
		$ 656,000
Carbon Regeneration		
	1965	191,000
	1968	2,000
		$ 193,000

SECTION XXVI

ACKNOWLEDGEMENTS

Environmental Protection Agency Project WPRD 52-01-67 is closely related to the entire South Tahoe Water Reclamation Plant project. Therefore acknowledgements are made, first for the Demonstration Project specifically, then for the development and construction of the Plant which made the Project possible.

The Demonstration Project (1967 - 1971)

Local Sponsors: South Tahoe Public Utility District Board of Directors: Robert W. Fesler (President), Robert Wakeman, Edward Hegarty, Donald Kortes, and Jerry Ream.

Data Collection: Plant Operation: Engineers: David R. Evans, Jerry C. Wilson, Robert L. Chapman, and Clinton E. Smith. Treatment Plant Operators: Earl Hardie (Chief Operator), Les Baker, Vern Trujillo, Al Kaufmann, Al Gunderson, Dick Miller, Ray Fieldcamp, Terry Guild, Lou Nagy, Bob Miller, Chet Horning, Jim Gorbet, Jerry Trauner, Mike Guthrie, Jim Dalecke, Tom Ontko, Everett Fox, and Kim Balbini. Plant Maintenance Crew: Murle Spencer (Supervisor), Conrad Ross, Willard Brown, Dick Vonderscher, and Merle Kobernus. Financial Data: David Callahan, Mary Parsley, Ruth Mounier. Indian Creek Reservoir Data: (Lake Tahoe Area Council) Dr. P. H. McGauhey, Dr. D. B. Porcella, and Dr. Gordon Dugan.

Final Report Preparation. Engineers: David R. Evans, Jerry C. Wilson, and Russell L. Culp. Stenographers: Charlotte Corday and Kay Price.

Technical Advice and General Supervision. District: Harlan E. Moyer, Russell L. Culp, and Gene Suhr. EPA: Dr. Robert B. Dean, Dr. David Stephan, Dr. Frank Middleton, Dr. Joseph Farrell, John C. Merrell, Jerry Troyan, and Robert Wills.

The Advanced Wastewater Treatment Plant (1961 - 1971)

The Demonstration Project was made possible by the existence of the advanced wastewater treatment plant of the South Tahoe Public Utility District. The total effort which culminated in the completion of this plant includes ten years of research, pilot plant work, process development, engineering design, construction, and operation. It also involved leadership, public support, political support, financial planning, counselling, management, and cooperation among many local, state, federal, and private agencies. In all facets of the work hundreds of people were involved, so that it is not possible to give individual recognition in all cases but only to list some by organization title.

Leadership. South Tahoe Public Utility District, Directors: Robert W. Fesler, Robert Wakeman, Donald H. Kortes, Edward Hegarty, Jerry Ream, Donald L. Clarke, Frank C. Souza, Thomas L. Stewart, and Donald Bickle.

Research and Unit Process Development. Original Concept: Ralph E. Roderick, Cornell, Howland, Hayes & Merryfield (CH_2M). Lime Treatment for Phosphorus Removal: Russell L. Culp, CH_2M. Lime Recalcining: CH_2M, Gene Suhr, Russell L. Culp; B-S-P Corp. Ammonia Stripping: CH_2M, Russell L. Culp, Gordon Culp, Robert Chapman, David Evans; Clair A. Hill & Associates, Al Slechta, Clinton Smith, Jerry Wilson. Two-Stage Recarbonation: CH_2M, Russell L. Culp, Gene Suhr. Mixed-Media Filtration: Microfloc, Inc., Walter Conley, Archie Rice; CH_2M, Ralph Roderick, Russell L. Culp. Granular Activated Carbon Adsorption: U. S. Public Health Service, Dr. Frank Middleton; Pittsburgh Activated Carbon Co., Don Hager; Microfloc, Inc., Walter Conley, Archie Rice; CH_2M, Gene Suhr, Russell L. Culp. Granular Carbon Regeneration: Carbon Manufacturers, Pittsburgh Activated Carbon Company, Atlas Chemical Company, and others; EPA, Dr. Frank Middleton; CH_2M, Gene Suhr, Russell L. Culp; Pomona Project, Frank Dryden; Nassau County Project, John Rose.

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Cooperating Pollution Control Agencies. EPA: Dr. David Stephan, Dr. Robert Dean, Dr. Frank Middleton, and others. California Water Resources Control Board: Paul Bonderson, Jack Leggett, Fred McLaren, David DuBois: Nevada State Department of Health: Wallace White, Ernest Gregory.

Administration and Management. Board of Directors, South Tahoe Public Utility District, Win Priday, Harlan E. Moyer, David Callahan, and Russell Culp.

Legal Counsel. John C. Weidman; and firm of Wilson, Jones, Morton, and Lynch, Robert Hill, Kenneth Jones, John Lynch.

Plant Construction Contractors. C. Norman Peterson Company, California Filter Company, Rothschild, Raffin and Weirick, B-S-P Corporation, P-M-I Corporation.

Major Equipment Suppliers. Allis Chalmers Mfg. Company, Autocon Industries, BSP Corporation, Bird Machine Company, Byron Jackson Pump Division of Borg Warner Corporation, Certain-teed Products Corporation and Johns - Manville Corporation, Chicago Bridge and Iron Company, Dorr-Oliver, Inc., General Services Company - Flomatcher Division, Komline-Sanderson Engineering Corporation, Link Belt Company, Marley Company, Neptune Microfloc, Inc., Pacific Clay Products, Rex Chainbelt Company, Inc., United Concrete Pipe Corporation, U.S. Electrical Motors, Inc., Wallace and Tiernan, Inc., Westinghouse Electrical Corporation.

On-The-Job-Training of Operators. CH_2M: Russell L. Culp, Gene Suhr, Robert Chapman, David Evans. Clair A. Hill and Associates: Clinton Smith, Jerry Wilson, Harlan E. Moyer. Neptune Microfloc, Inc.: Walter Conley, William Ettlich. BSP Corporation: Richard Stroshane, J.S. Roberts, Paul Cardinal, Bob Tillotson. Bird Machine Company: Ted Durst, Jim Bailey, Cliff Amerro. Komline-Sanderson Engineering Corporation, W. E. Mayo. Dorr-Oliver, Inc.

Plant Operations and Maintenance. Plant operators and maintenance crew as previously listed under "Data Collection".

Operation and Maintenance of Collection System, Pump Stations, and Export Facilities. Pump Stations and Export Facilities: Lee Chada (Superintendent), Bernie Montbriand (Supervisor), Al Harris, Lowell Hardie, Harry Hanson, Bob Eppler. Collection System: M. W. Fagot, Norman Thomas, Gene Eppler, W. J. Bussboom, Richard DeVee, Mike McCoy, Greg James, Brian Bethel.

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APPENDIX A

UNITED STATES VISITORS
SOUTH LAKE TAHOE WATER RECLAMATION PLANT

June 1964 to January 1971

	1964	1965	1966	1967	1968	1969	1970	Total
Alabama						2		2
Alaska						2		2
Arizona		1				1		2
California	82	188	119	68	179	729	1126	2491
Colorado		2		1	1	5	7	16
Connecticut			3		2	4		9
Delaware		2		2	3	1	8	16
District of Columbia		1	4	2		11	10	28
Florida				1		1	6	8
Georgia						5	2	7
Hawaii			2			1	8	11
Idaho					1	1	3	5
Illinois		2	3	2	11	10	10	38
Iowa		1				6	9	16
Kansas	2		1		5			8
Maine						1		1
Maryland		10		6	2	5	8	31
Massachusetts		3	2	2	3	5	7	22
Michigan		1		1	3	4	6	15
Minnesota		1			1	8	10	20
Mississippi		2				3		5
Missouri						4	4	8
Montana						2	2	4
Nebraska		1				1		2
Nevada	17	30	10	4	8	43	145	257
New Jersey		1	3	2	2	1	17	26
New Mexico						1		1
New York		5		2	8	9	15	39
North Carolina						1		1
Ohio	2	5	1		3	9	18	38
Oklahoma			1		1	1		3
Oregon	1	8	8	3	7	43	16	86
Pennsylvania		5	5	5	4	10	12	41
South Carolina				1		1		2
Tennessee							2	2
Texas				1	1	6	8	16
Utah		5		1	2	12	8	28
Virginia				1		6	7	14
Washington		1	3	2	5	10	9	30
Wisconsin		2			1	3		6
Wyoming	1				4	2		7
Total	105	277	165	107	257	970	1483	3364

FOREIGN VISITORS
SOUTH LAKE TAHOE WATER RECLAMATION PLANT

January 1965 - January 1971

COUNTRY	1965	1966	1967	1968	1969	1970	Total
Argentina				1	1	1	3
Australia	1			3	2	3	9
Belgium						3	3
Brazil				5	2	5	12
British Honduras						1	1
Canada			1	1	14	9	25
Czechoslovakia					4	2	6
Denmark					2	1	3
England (United Kingdom)	1		2	3	3	11	20
France		5	3	6		6	20
Ghana					1		1
Hong Kong						1	1
India			2		2	1	5
Indonesia					3		3
Israel		1		1		3	5
Italy					1		1
Japan	3	7		5	5	23	43
Netherlands						1	1
New Zealand						1	1
Norway						2	2
Poland			3				3
Republic of China					1		1
Russia						6	6
Singapore					2		2
Spain						1	1
Sweden		4	2	1	3	7	17
Switzerland			3			1	4
Thailand				2			2
Turkey					2		2
Union of South Africa			2	2	3	15	22
Uruguay		1					1
Venezuela					1	1	2
West Germany			5		1	16	22
West Pakistan	2						2
Totals	7	18	23	30	53	121	252

APPENDIX B

TABULATIONS
OF
DAILY
LABORATORY AND FLOW DATA

SOUTH TAHOE PUBLIC UTILITY DISTRICT - WATER RENOVATION PLANT
MONTHLY TABULATION OF FLOW AND LABORATORY DATA

April (Month) 1968 (Year)

(First Month of Export)

DATE

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Plant Flow, MG	2.1	1.7	1.7	2.1	2.1	2.2	2.2	2.2	2.2	1.9	2.2	2.0	2.0	1.8	2.0	1.8
Peak Flow Rate MGD													4.6	4.5	5.3	4.0
Flow Into Indian Creek Reservoir, MG	2.1	1.7	1.7	2.1	2.1	2.2	2.2	2.2	2.2	1.9	2.2	2.0	2.0	1.8	2.0	1.8
Flow From Indian Creek Reservoir, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Flow From Other Outlets, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-day BOD (mg/l)								0.9	1.0	0.5	1.5	1.0			1.5	0.7
COD (mg/l)								7.7	10	12	9.5	8.1			11	20
Suspended Solids (mg/l)								11*	5*	1	1	1			1	3*
MBAS (mg/l)								0	.01	.01	.01	.01			.01	.01
Turbidity, J U	1.7	1.3	0.6	0.6	1.0	1.0	0.9	1.3	1.3	1.5	0.5	0.5	0.6	0.7	1.0	1.6
pH (pH units)								8.0	7.7	7.9	7.9	7.8			7.6	8.6
Chlorine Residual (mg/l)																
Instantaneous								1.8		2.0	2.5	2.5			1.8	2.5
30 Min. Contact																
Luther Pass Station									1.5	1.3	1.5	1.5			1.0	1.5
Coliforms (MPN/100ml)															<2.2	<2.2
Nitrogen (mg/l N)																
organic																
ammonia															20	27
nitrate															0.6	<.1
nitrite																
Phosphate (mg/l P)								.04				.09				
Alkalinity (mg/l $CaCO_3$)												229				
Hardness (mg/l $CaCO_3$)																
Total Dissolved Solids (mg/l)																
Chloride (mg/l)												4.0				

	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Plant Flow, MG	2.0	1.9	1.8	2.4	1.9	1.9	1.8	1.8	1.6	0.9	2.2	2.0	1.8	1.5	
Peak Flow Rate MGD	4.7	4.5	4.6	4.5	5.2	4.1	5.0	5.2	4.7	5.0	4.9	4.1	4.9	3.8	
Flow Into Indian Creek Reservoir, MG	2.0	1.9	1.8	2.4	1.9	1.9	1.8	1.8	1.6	0.9	2.0	2.0	1.8	1.5	
Flow From Indian Creek Reservoir, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Total Flow From Other Outlets, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
5-day BOD (mg/l)	1.2	0.7	0.7			4.3	2.9	4.8	3.2	4.1		1.3	1.3	[illegible]	
COD (mg/l)	21	14	19			12	22	21	18	18			21	22	
Suspended Solids (mg/l)	1	8*	0			5*	4*	5*	4*	2*			1	1	
MBAS (mg/l)	.01	.01	.03			.06	.03	.03	.03	.06			.03	.05	
Turbidity, J U	1.5	1.0	0.9	1.2	1.2	1.3	1.8	1.3	1.5	1.5	1.4	2.0	1.8	2.0	
pH (pH units)	8.5	8.5	8.7			9.0	8.7	8.7	8.6	8.7			7.9	7.7	
Chlorine Residual (mg/l)															
Instantaneous	2.5	0.1	1.0	2.5		2.5	2.5	3.7	3.9	2.7			3.1	3.4	
30 Min. Contact															
Luther Pass Station	1.0	2.0	2.0	2.0		2.5	1.5	2.9	2.8	2.7			3.3	2.4	
Coliforms (MPN/100ml)	<2.2	<2.2	9.2			<2.2	<2.2	<2.2	<2.2	<2.2		<2.2	2.2	<2.2	
Nitrogen (mg/l N)															
organic			0							0					
ammonia			21							23					
nitrate			0							.01					
nitrite															
Phosphate (mg/l P)	0.4	0.3	0.5	0.7		0.4	0.5	0.3	0.5	0.4					
Alkalinity (mg/l $CaCO_3$)			265						273	258					
Hardness (mg/l $CaCO_3$)										190					
Total Dissolved Solids (mg/l)			248							192					
Chloride (mg/l)			34							35					

Carbon lines from row columns

SOUTH TAHOE PUBLIC UTILITY DISTRICT - WATER RENOVATION PLANT
MONTHLY TABULATION OF FLOW AND LABORATORY DATA

May (Month) 1968 (Year)

DATE

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Plant Flow, MG	1.9	1.9	2.0	2.2	2.2	1.9	1.9	1.9	1.9	1.9	2.4	2.1	1.9	2.0	1.9	1.9	2.0	2.3	2.1	2.1	1.9	2.0	1.9	1.9	2.4	2.1	1.9	2.1	2.1	2.3	2.4
Peak Flow Rate MGD	4.1	4.0	4.2	4.6	4.6	5.0	5.9	6.0	4.3	5.9	4.8	5.4	5.5	4.6	4.5	5.8	4.0	4.7	4.3	4.1	4.6	5.1	4.2	4.8	5.4	5.2	5.2	5.3	4.5	5.3	5.4
Flow Into Indian Creek Reservoir, MG	1.9	1.9	2.0	2.2	2.2	1.9	1.9	1.9	1.9	1.9	2.4	2.1	1.9	2.0	1.9	1.9	2.0	2.3	2.1	2.1	1.9	2.0	1.9	1.9	2.4	2.1	1.9	2.1	2.1	2.3	2.4
Flow From Indian Creek Reservoir, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Flow From Other Outlets, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-day BOD (mg/l)	-	-	1.8			0.8	2.9	0.7	0.9	0.8			1.4	2.5	0.5	0.6	0.9			1.2	2.0	2.3	1.9	0.9			3.4	3.4	3.5	3.3	3.3
COD (mg/l)	19	15	16			16	11	11	13	8			5	10	7	9	9			11	15	16	17	13			9	11	13	6	11
Suspended Solids (mg/l)	2	0	2			1	2	4	2	1			1	5	0	0	0			0	0	0	0	0			0	0	0	0	0
MBAS (mg/l)	.05	.05	.05			.05	.05	.03	.07	.10			.11	.15	.17	.16	.17			.12	.14	.13	.14	.14			.16	.17	.28	0	.20
Turbidity, J U	1.3	0.8	0.6			0.5	0.7	1.0	0.5	0.5			0.8	0.6	1.0	0.7	0.7			0.7	0.7	0.7	0.7	0.6		0.5	0.3	0.6	0.3	0.2	0.3
pH (pH units)	7.7	7.9	7.7			6.8	6.9	7.1	7.1	7.1			7.2	6.8	7.0	7.3	7.2			7.2	7.5	7.3	6.[illegible]	7.1			7.1	7.3	7.3	7.1	7.3
Chlorine Residual (mg/l)	-																														
Instantaneous	2.7	2.7	3.6			3.5	-	4.3	1.2	0.9		2.0	0.9	1.2	1.7	2.5	2.9		2.6	0.9	1.5	1.6	1.9	2.2		0.9	2.8	1.7	3.1	[illegible].2	1.7
30 Min. Contact	-	-	-			-	-	-	-	-		-	-	-	-	-	-		-	-	-	-	-	-		-	-	-	-	-	-
Luther Pass Station	2.0	2.0	2.6			2.8	0.1	0.1	1.1	0.8		1.3	0.5	0.3	0.7	0.8	1.1		1.5	1.5	1.5	1.4	1.[illegible]	1.4		1.0	0.3	0.3	1.1	-	1.2
Coliforms (MPN/100ml)	<2.2	<2.2	<2.2			<2.2	<2.2	5.1	<2.2	5.1		2.2	<2.2	5.1		>16	<2.2		<2.2	>16	<2.2	16	-	<2.2		<2.2	>16	<2.2	<2.2	-	<2.2
Nitrogen (mg/l N)																															
organic									-	0							0							-							-
ammonia			18.6						-	0							0							0.3							0
nitrate			0.1						4.3	6.3							12							6.9							11.3
nitrite			-						5.7	3.8							0.4							0.6							2.8
Phosphate (mg/l P)	.03	.03	.09			.31	.53	.33	.43	.41			1.0	0.[illegible]	1.2	2.0	-			2.3	2.7	2.7	2.[illegible]	1.7			1.2	1.5	1.[illegible]		3.8
Alkalinity(mg/l $CaCO_3$)			230							157							145							183							270
Hardness(mg/l $CaCO_3$)			130							150							168							150							184
Total Dissolved Solids(mg/l)			328							-							-							360							-
Chloride (mg/l)			35							15							37							33							31
lfate (mg/l)										25							-							18							24

SOUTH TAHOE PUBLIC UTILITY DISTRICT - WATER RENOVATION PLANT
MONTHLY TABULATION OF FLOW AND LABORATORY DATA

June (Month) 1968 (Year)

	DATE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Plant Flow, MG	2.3	2.2	1.9	2.1	1.9	2.3	2.0	2.3	2.2	2.1	2.3	2.1	2.3	2.2	2.6	2.2	2.4	2.5	4.8	2.5	2.0	3.1	3.0	2.2	2.7	2.7	2.8	2.4	3.0	2.7	
Peak Flow Rate MGD	5.2	5.1	5.0	5.2	5.0	5.0	5.1	5.0	5.1	5.0	5.0	5.3	5.1	4.8	5.4	5.4	5.6	5.7	6.0	5.9	6.0	5.8	6.1	5.9	5.3	5.4	5.5	5.4	5.4	5.3	
Flow Into Indian Creek Reservoir, MG	2.3	2.2	1.9	2.1	1.9	2.3	2.0	2.3	2.2	2.1	2.3	2.1	2.3	2.2	2.6	2.2	2.4	2.5	4.8	0	0	3.1	3.0	2.2	2.7	2.7	2.8	2.4	3.0	2.7	
Flow From Indian Creek Reservoir, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Total Flow From Other Outlets, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
5-day BOD (mg/l)			1.1	4.9	6.4	6.7	4.8			0	0.4	1.5	4.4	2.7			5.9	5.4	6.0					5.2	5.1	4.5	4.4	5.4			
COD (mg/l)			6.3	7.1	6.1	6.8	6.5			5.2	10.	12	8.6	10			12	11	17					12	7	8	5	3.6			
Suspended Solids (mg/l)			0	0	0	0	0			3	0	0	0	0			0	2	4					2	1	0	1	0			
MBAS (mg/l)			.17	.20	.24	.17	.13			.17	.17	.17	.10	.13			.12	.12	.16					.13	.13	.13	.10	.11			
Turbidity, J U		0.3	0.2	0.2	0.4	0.3	0.3		0.4	0.3	0.6	0.6	0.4	0.4		0.5	0.6	0.5	0.5	No Export	No Export		0.4	0.3	0.3	0.3	0.3	1.0		0.4	
pH (pH units)		7.1	7.1	7.2	7.4	7.4	7.4		7.1	7.0	7.2	7.4	7.4	7.6		7.5	7.7	7.7	8.2				7.4	8.0	7.6	7.2	6.9	7.2		6.9	
Chlorine Residual (mg/l)																															
Instantaneous		2.6	1.1	1.3	0.4	1.2	2.1		1.9	0.7	.69	3.0	2.6	1.5		0.9	2.1	2.2	—	—	—		3.6	1.7	5.6	3.1	8.0	2.1		3.6	
30 Min. Contact																															
Luther Pass Station			.58	.64	0.4	.58	.44		1.7	.71	.48	.42	.63	.63		.45	.44	1.0	—	—	—		1.4	2.3	2.6	2.2	2.5	2.2		2.2	
Coliforms (MPN/100ml)		<2.2	<2.2	<2.2	<2.2	—	<2.2		<2.2	<2.2	2.2	5.1	—	<2.2		<2.2	<2.2	—	—	—	—		<2.2	<2.2	<2.2	<2.2				<2.2	
Nitrogen (mg/l N)																															
organic																															
ammonia							.12							2.8														13.8			
nitrate							12.3							7.1														4.5			
nitrite							0.8							0.6														0.8			
Phosphate (mg/ 1 P)			0.3		0.5	0.7	0.8			0.9	1.1	1.3		0.9			1.0	1.6	1.4	—	—			0.2	1.1	0.4	1.2	1.3			
Alkalinity(mg/l $CaCO_3$)							164							187														246			
Hardness(mg/l $CaCO_3$)							160							154														140			
Total Dissolved Solids(mg/l)							294							348														324			
Chloride (mg/l)							25							30														33			
Sulfate (mg/l)							23							28														25			

SOUTH TAHOE PUBLIC UTILITY DISTRICT - WATER RENOVATION PLANT
MONTHLY TABULATION OF FLOW AND LABORATORY DATA

JULY (Month) 1968 (Year)

DATE

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Plant Flow, MG	2.6	2.6	2.8	2.9	3.2	3.3	2.9	2.6	2.6	2.9	2.9	2.7	3.2	2.2	2.9	2.9	2.8	2.7	3.0	3.0	3.1	2.9	2.7	2.2	2.0	2.2	2.6	2.2	2.2	2.5	1.8
Peak Flow Rate MGD	5.7	5.5	5.5	5.7	6.1	6.7	6.2	6.2	6.0	5.4	—	6.1	6.1	5.6	5.6	5.8	5.9	6.0	6.3	6.1	5.9	6.0	6.0	6.0	5.9	5.4	5.4	5.9	6.5	5.4	5.7
Flow Into Indian Creek Reservoir, MG	2.6	2.6	2.8	2.9	3.2	3.3	2.9	2.6	2.6	2.9	2.9	2.7	3.2	2.2	2.9	2.9	2.8	2.7	3.0	3.0	3.1	2.9	2.7	2.2	2.0	2.2	2.6	2.2	2.2	2.5	1.8
Flow From Indian Creek Reservoir, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.2	7.1	8.7	8.7	8.7	8.7	8.7	4.3	0	0	0	3.8	6.5	6.5	6.5	6.5	5.7
Total Flow From Other Outlets, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-day BOD (mg/l)	3.6*	4.3*	3.7*	4.4*	3.5*			7.0*	6.4*	6.6*	6.7*	6.6*			6.6*	7.0*	7.4*	6.4*	7.8*			2.2	.01	0.4	0.3	0.2			0.7	1.1	0.9
COD (mg/l)	8.0	4.2	9.8		11.2				18.1	10.9	18.1	16.8			16.3	17.2	12.3	2.1	12.6			11.2	16.7	10.9	9.2	14.4			15.4	12.5	14.5
Suspended Solids (mg/l)	1.0	2.0	0.0		0.0			2.0	0.0	2.0	2.0	4.0			4.0	0.0	1.0	0.0	7.0			2.0	1.0	1.0	2.0	1.0			1.0	0.5	0.0
MBAS (mg/l)	.13	.11	.10		.10			.12	.10	.19	.18	.18			.20	.20	.12		.12			.12	.09	.12		.12			.13	.16	.18
Turbidity, J U	0.3	0.3	0.2	0.2	0.3		0.5	0.5	0.5	0.3	0.5	0.4		0.5	0.3	0.3	0.3	0.2	0.2		0.2	0.2	0.2	0.2	0.2	1.0		0.3	0.2	0.2	0.1
pH (pH units)	7.5	7.4	7.2		7.2		7.4	7.0	7.2	7.8	7.9	7.6		7.4	7.5	7.5	7.6	7.4	7.8			8.1	7.5	7.6	7.2	7.1		7.7	7.3	7.5	7.6
Chlorine Residual (mg/l)																															
Instantaneous	1.9	2.6	4.3	3.5	2.8		2.8	2.6	1.3	1.7	1.2	1.4		1.3	1.5	1.0	1.1	2.1			1.8	1.1	2.1	3.0	3.4	2.0		3.9	3.2	3.5	3.2
30 Min. Contact																															
Luther Pass Station	2.1	2.0	2.1	2.5	2.6		1.7	1.5	1.0	1.3	0.7	0.7		0.9	1.1	1.3	1.7	0.8	2.0		1.0	1.0	1.2	1.2	1.5	1.4		3.1	1.6	2.9	1.2
Coliforms (MPN/100ml)	<2.2	<2.2	<2.2		<2.2		>16	<2.2	2.2	<2.2		<2.2		<2.2	2.2	>16	<2.2		<2.2		<2.2	>16	9.2	5.1		<2.2		>16	>16	>16	>16
Nitrogen (mg/l N)																															
[illegible] *NOTE:			June 4 thru July 19, 1968 - False high, BOD readings were obtained because samples were collected prior to chlorination of wastewater, after July 20, BOD's were run on samples collected after chlorination of wastewater.																												
ammonia					13.6							6.3														9.4					
nitrate					1.8							5.1							9.6							6.7					
nitrite					1.9							3.5							1.7							1.6					
Phosphate (mg/ l P)	1.8	1.3	1.2		1.4			1.8	1.8	1.6	0.6	1.3			1.7	1.7	1.0	0.4	1.0			0.8	1.4	1.1	0.8	1.3			0.6	0.8	
Alkalinity (mg/l $CaCO_3$)					232							208				209	203	228	187			206	224	226	213	212			208	193	0.6
Hardness (mg/l $CaCO_3$)					146							138							134							150					181
Total Dissolved Solids (mg/l)					342							260							303							179					
Chloride (mg/l)					29.5							21.3							63.8							42.5					
Sulfate (mg/l)					30.0							22.8							27							52					

SOUTH TAHOE PUBLIC UTILITY DISTRICT - WATER RENOVATION PLANT
MONTHLY TABULATION OF FLOW AND LABORATORY DATA

AUGUST (Month) 1968 (Year)

DATE

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Plant Flow, MG	2.6	1.9	2.3	2.3	2.4	2.5	2.6	2.5	2.4	2.4	2.3	2.5	2.6	2.7	2.5	2.3	2.8	2.5	2.6	2.4	2.8	2.5	2.5	2.6	2.4	2.7	2.5	2.5	2.3	1.9	1.9
Peak Flow Rate MGD	4.6	5.2	5.1	5.0	5.1	5.1	5.3	6.1	5.1	5.5	5.1	6.1	5.6	6.5	5.3	5.8	5.6	5.4	6.1	5.7	6.4	5.7	5.6	5.6	6.1	5.6	5.8	5.7	6.1	5.7	5.8
Flow Into Indian Creek Reservoir, MG	2.6	1.9	2.3	2.3	2.4	2.5	2.6	2.5	2.4	2.4	2.3	2.5	2.6	2.7	2.5	2.3	2.8	2.5	2.6	2.4	2.8	2.5	2.5	2.6	2.4	2.7	2.5	2.5	2.3	1.9	1.9
Flow From Indian Creek Reservoir, MG	0	0	0	0	0	0	0	0	0	0	0	0	3.8	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	5.8	0	0	0	0	0
Total Flow From Other Outlets, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	.07	.07	.07	0	0	.07	.07	.07	.07	.07	0
5-day BOD (mg/l)	0.1	1.5			0.4	0.4	0.6	1.3	1.0			0.1	0.3	0.6	0.4	0.9			0.4	0.8	0.4	0.5	0.5			0.4	0.4	0.7	0.6	-	
COD (mg/l)	15.2	17.3			15.4	11.8	14.9	13.4	13.1			13.4	9.9	9.3	11.8	15.0			13.3	11.5	10.5	14.1	10.9			16.8	13.6	14.1	7.9	12.6	
Suspended Solids (mg/l)	0	1.0			3.0	0.0	0.0	0.2	1.0			0.0	1.0	0.0	0.0	0.0			0.0	1.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	0.0	
MBAS (mg/l)	.15	.17			.19	.19	.18	.18	.19			.16	.19	.19	.18	.19			.16	.18	.18	.18	-			-	.16	-	.12	.19	
Turbidity, J U	0.2	0.2		0.3	0.2	0.2	0.1	0.2	0.2		0.3	0.1	0.2	0.2	0.2	0.2		0.2	0.1	0.1	0.1	0.1	0.1		0.1	0.1	0.1	0.1	0.1	0.1	
pH (pH units)	8.0	8.4		7.5	7.8	7.4	7.5	7.3	7.1		7.2	7.2	7.5	7.4	7.4	7.4		7.0	7.6	7.6	7.6	7.3	-			-		7.6	7.4	7.2	
Chlorine Residual (mg/l)																															
Instantaneous	2.8	2.0		1.6	1.9	1.8	2.0	2.8	2.2		2.8	5.2	3.7	3.3	2.8	3.5		1.7	4.4	3.9	2.9	6.5	5.6		5.1	6.6	3.7	3.6	5.2	4.6	
30 Min. Contact																															
Luther Pass Station	2.6	2.5		1.3	1.9	1.6	1.8	1.9	1.3		1.0	1.2	3.1	2.2	2.8	2.1		2.3	1.4	3.5	2.6	3.1	4.2		3.9	5.0	3.7	2.9	3.1	3.4	
Coliforms (MPN/100ml)	-	16		5.1	>16	>16	2.2	-	>16		>16	>16	<2.2	<2.2	-	<2.2		<2.2	2.2	2.2	<2.2	-	<2.2		2.2	>16	<2.2	<2.2	-	<2.2	
Nitrogen (mg/l N)																															
organic																															
ammonia		7.9							8.0							8.4						8.5									
nitrate		5.8							7.2							6.0						6.3									
nitrite		3.9							3.6							2.7						0.7									
Phosphate (mg/ l P)	1.2	1.0			0.8	0.5	0.2	0.3	0.4			0.02	0.4	.33	0.4	0.3			0.13	0.36	0.11	0.2				0.4	0.7	0.8	0.5	0.5	
Alkalinity(mg/l $CaCO_3$)	189	173			202	217	212	221	232			234	228	214	226	236			264	234	238	245						257	257	254	
Hardness(mg/l $CaCO_3$)		112							188													168								142	
Total Dissolved Solids(mg/l)		190							204													376								330	
Chloride (mg/l)		39							32													37								31	
Sulfate (mg/l)		28							2													24								9	

SOUTH TAHOE PUBLIC UTILITY DISTRICT - WATER RENOVATION PLANT
MONTHLY TABULATION OF FLOW AND LABORATORY DATA

September (Month) 1968 (Year)

DATE

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Plant Flow, MG	2.5	2.4	2.1	2.2	1.9	2.1	2.2	2.1	2.1	2.0	2.0	2.2	1.8	2.0	1.6	2.0	1.7	1.9	2.1	2.2	1.9	1.8	1.7	1.7	1.7	1.8	1.6	2.0	1.8	1.8	
Peak Flow Rate MGD	5.7	6.1	5.3	5.1	4.8	5.3	5.3	5.3	4.8	4.5	4.3	2.9	3.0	3.2	3.1	3.1	3.1	3.1	2.9	2.9	3.0	3.2	3.1	3.0	3.0	2.9	2.8	2.9	2.6	2.7	
Flow Into Indian Creek Reservoir, MG	2.5	2.2	2.0	2.0	1.8	1.9	2.2	2.1	2.0	1.8	1.9	2.0	1.7	2.0	1.6	1.8	1.6	1.7	2.0	2.0	0	0	1.6	1.6	1.6	1.5	1.5	2.0	1.8	1.7	
Flow From Indian Creek Reservoir, MG	0	0	3.7	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	5.2	2.5	0	0	0	0	0	0	0	0	0	0	0	0	
Total Flow From Other Outlets, MG	0	0.2	0.1	0.2	0.1	0.2	0	0	0.1	0.2	0.1	0.2	0.1	0	0	0.2	0.1	0.2	0.1	0.2	1.9	1.8	0.1	0.2	0.1	0.2	0.1	0	0	0.1	
5-day BOD (mg/l)		0.0	0.7	0.8	0.2	0.4			0.7	1.4	0.3	0.4	0.5			0.5	0.4	0.2	0.3				1.2	0.9	1.3	0.6	0.1			0.2	
COD (mg/l)		13.3	9.7	9.9	11.5	12.5			4.5	9.3	7.3	7.3	7.6			9.2	9.5	8.9	9.0	8.1			11.0	9.5	8.8	8.9	5.5			8.1	
Suspended Solids (mg/l)		1.0	1.0	1.0	0.0	0.0			0.0	1.0	0.0	0.0	1.0			0.0	0.0	0.0	0.0	2.0			0.0	0.0	1.0	0.0	1.0			0.0	
MBAS (mg/l)	.19		.16			.11				.11	.14		.16														0.08				
Turbidity, J U	0.3	0.2	0.2	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.4	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	
pH (pH units)	6.8	7.5	7.3	7.5	7.1	7.2		7.0	7.1	7.3	7.2	7.4	7.5		7.4	7.4	7.2	7.1	7.3	7.3		6.8	7.6	7.5	7.1	7.1	7.2		7.0	7.7	
Chlorine Residual (mg/l)																															
Instantaneous	3.0	2.7	6.2	8.0	8.4	8.5		8.5	6.2		5.4	1.6	14.7		3.9	4.2	3.7	6.0	8.4	5.6		4.5	8.0	4.5	6.0	5.3	5.1		3.1	3.6	
30 Min. Contact																															
Luther Pass Station	2.7	2.2	3.1	2.7	4.0	6.5		6.7	1.8	0.2		0.8	1.8		1.7	1.9	1.3	2.8	2.2	2.4			3.0	3.0	2.7	2.8	2.8		1.8	2.1	
Coliforms (MPN/100ml)	<2.2	2.2	<2.2	<2.2		<2.2		<2.2	>16	<2.2	<2.2		<2.2		<2.2	<2.2	<2.2	<2.2		<2.2			<2.2	<2.2	<2.2		<2.2		<2.2	<2.2	
Nitrogen (mg/1 N)																															
organic																															
ammonia						9.3							2.6														0.5				
nitrate						2.5							7.5														8.0				
nitrite						1.3							1.3																		
Phosphate (mg/1 P)		0.80	0.00	0.12	0.00	0.17			0.11	0.14	0.11	0.10	0.08					0.07													
Alkalinity(mg/1 CaCO$_3$)		233	270	255	235	275			256	263	250	235	205			220	235	252	266	268			270	274	250	229	260			289	
Hardness(mg/1 CaCO$_3$)						176							170							122							174				
Total Dissolved Solids(mg/l)						376							383							412							295				
Chloride (mg/l)						32							28							32							32				
Sulfate (mg/l)						26							26							24							30				

SOUTH TAHOE PUBLIC UTILITY DISTRICT - WATER RENOVATION PLANT
MONTHLY TABULATION OF FLOW AND LABORATOR DATA

October (Month) 1968 (Year)

	DATE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Plant Flow, MG	1.4	1.9	1.8	1.8	1.6	1.8	1.5	1.7	1.7	1.7	1.5	1.5	1.7	1.5	1.7	1.4	1.4	1.4	1.7	1.3	2.0	1.7	1.7	1.5	1.4	1.5	1.3	1.3	1.1	1.2	1.2
Peak Flow Rate MGD	4.0	4.0	4.4	4.1	4.1	4.0	3.8	3.9	4.2	3.8	3.9	3.7	3.8	3.8	3.6	3.7	4.0	3.9	4.1	4.0	3.9	4.1	4.0	3.9	4.0	4.0	4.0	3.7	3.4	3.6	3.5
Flow Into Indian Creek Reservoir, MG	1.3	1.8	1.7	1.8	1.6	1.8	1.5	1.7	1.7	1.7	1.5	1.5	1.7	1.5	1.7	1.4	1.4	1.4	1.7	1.3	2.0	1.7	1.7	1.5	1.4	1.5	1.3	1.3	1.1	1.2	1.2
Flow From Indian Creek Reservoir, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Flow From Other Outlets, MG	0.1	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-day BOD (mg/l)	1.2	1.2	0.6	0.5			3.2	1.4	0.4	1.3	0.3			1.1	1.0	1.2	0.7	0.5			0.1	1.0	-	0.2	0.1			2.1	1.4	1.5	1.3
COD (mg/l)	7.2	6.5	7.5	7.3			8.5	7.5	8.0	8.3	5.0			13.5	15.5	13.1	11.3	17.8			-	17.0	16.3	18.0	17.8			11.8	17.3	18.7	20.2
Suspended Solids (mg/l)	0	0	0	0			0	0	0	0	0			0	0	0	0	0			0	0	0	0	0			1.0	0	0	0
MBAS (mg/l)										0.09																					
Turbidity, J U	0.1	0.2	0.2	0.1		0.3	0.2	0.3	0.3	0.1	0.2		0.4	0.2	0.3	0.3	1.4	1.7	0.7		1.5	1.5	1.0	0.8	1.2		0.5	1.9	1.4	1.2	1.4
pH (pH units)	7.6	7.4	7.2	7.4		6.8	7.0	7.4	7.2	7.2	7.5		7.1	7.6	7.7	7.6	7.8	8.4	8.5		8.6	8.7	8.6	8.3	8.7		8.5	8.7	8.8	8.6	8.5
Chlorine Residual (mg/l)																															
Instantaneous	1.1	3.0	5.4	1.7		0	0	2.0	4.9	6.8	12.2		21.1	8.9	1.7	3.4	2.7	8.9	4.6		3.2	5.0		5.6	17.8		7.4	1.0	8.4	4.7	2.7
30 Min. Contact																															
Luther Pass Station	2.6	3.0	2.8	2.9		0	0	0	0	3.4	3.1		12.1	12.1	3.8	1.4	0	3.6	2.0		2.8	2.9	2.9	0	3.8		4.2	8.9	3.9	2.7	4.0
Coliforms (MPN/100ml)	<2.2	-	2.2	<2.2		16	>16	>16	>16	-	5.1		16	>2.2	>16	5.1	-	<2.2	<2.2		<2.2	<2.2	<2.2	-	<2.2		<2.2	<2.2	<2.2	<2.2	<2.2
Nitrogen (mg/1 N)																															
organic																															
ammonia			6.8	20.0					18.9																9.3						
nitrate				0.08					0.4																0						
nitrite									0.48																0.08						
Phosphate (mg/ 1 P)			0.13					01.5	0.14	0.07											0.64	0.62			0.53				0.51		
Alkalinity(mg/1 $CaCO_3$)	297	287	272	289			266	255	226	253	300			285	263	227	235	213			220	230	238	220	223			236	240	231	212
Hardness(mg/1 $CaCO_3$)				158							114							112							130						
Total Dissolved Solids(mg/l)				362							382							248							284						
Chloride (mg/l)				30							39							33.5							32						
Sulfate				28							26							28.0							28						

SOUTH TAHOE PUBLIC UTILITY DISTRICT - WATER RENOVATION PLANT
MONTHLY TABULATION OF FLOW AND LABORATORY DATA

NOVEMBER (Month) 1968 (Year)

	DATE																														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Plant Flow, M G	1.8	1.8	2.2	1.5	1.4	1.3	1.5	1.5	1.8	1.6	1.7	1.8	1.7	1.5	1.6	1.5	1.6	1.5	1.0	1.2	1.3	1.6	1.4	1.4	1.6	1.4	1.5	1.7	1.9	1.7	
Peak Flow Rate MGD	3.1	2.6	2.6	2.9	3.2	3.2	2.9	2.6	2.9	3.1	3.8	3.6	2.4	2.4	2.2	2.5	2.4	2.4	2.3	2.4	3.1	3.6	5.3	3.6	3.0	4.7	3.2	3.0	2.7	2.8	
Flow Into Indian Creek Reservoir, MG	1.8	1.8	2.2	1.5	1.4	1.3	1.5	1.5	1.8	1.6	1.7	1.8	1.7	0.7	0	0	0	0	0	0.7	1.3	1.6	1.4	1.4	1.6	1.4	1.5	1.7	1.9	1.7	
Flow From Indian Creek Reservoir, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Total Flow From Other Outlets, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
5-day BOD (mg/l)	0.9			0.2	1.2	0.4		0.2			0.0	0.2	0.5	0.3	0.1			0.0		0.0	1.6	1.1					1.8	2.0			
COD (mg/l)	16.1			16.8	22.8	13.8	12.5	13.9			15.9	15.4	14.7	17.3	25.3			13.1	15.9	7.1		7.6			20.7	17.0	11.5	10.3	7.3		
Suspended Solids (mg/l)	0			2	0	0	0	0			8	0	0	0	0			0	0	0											
M B A S (mg/l)	0.26																			0.09	0.09	0.11			0.15		0.25	0.13			
Turbidity, J U	1.6		0.5	1.0	1.6	1.4	1.2	1.2		0.5	1.5	1.7	1.5	1.5	1.9		1.8	2.7	2.9			0.7		1.4	1.6	1.2	1.1	0.6	1.2		
pH (pH units)	9.1		8.5	8.4	8.6	8.6	8.9	8.7		8.6	8.4	8.6	8.8	8.7	8.4		6.9	7.2	7.5	7.1	7.5	7.0		8.5	7.7	8.0	8.6	7.7	7.4		
Chlorine Residual(mg/l)																															
Instantaneous	3.6		8.9	4.3	9.9	2.0		3.5		4.3	4.0	3.8	4.0	3.1	6.7		4.5	7.9	5.8	1.6		0		1.0	2.7	2.8	2.4	2.9	2.8		
30 Min. Contact																															
Luther Pass Station	3.1		4.5	6.9	3.0	1.8	1.7	1.2		2.1	3.1	2.8	2.8	2.9	2.9							1.2		0.7	1.2	1.3	1.5	2.0	2.5		
Coliforms (MPN/100 ml)			<2.2	<2.2	<2.2	<2.2		<2.2		<2.2	<2.2	<2.2	<2.2									<2.2		<2.2		<2.2	<2.2		<2.2		
Nitrogen (mg/l N)																															
organic																															
ammonia	14.2																														
nitrate																			0	0.12	0.6	0.23			0.17	0.4	0.23	0.09	0.22		
nitrite	0.22																		0.12	0.92	0.07				0.08	0.07	0.03	0.01	0.04		
Phosphate (mg/l P)	0.37																		4.9	1.6		0.06			0.42	0.62	0.75				
Alkalinity (mg/l $CaCO_3$)	190			230	228	214	210	193			218	214	235	213	215			190	178	163	157	113		118	49	42	225	250	235		
Hardness (mg/l $CaCO_3$)	108							138													88	76	72		144	152	154	160	154		
Total Dissolved Solids(mg/l)	310							306							298																
Chloride (mg/l)	39							29													32	28	25		19	31	23	27	23		
Sulfate (mg/l)	45							28													40	40	42		13	35	38	33	19		

SOUTH TAHOE PUBLIC UTILITY DISTRICT - WATER RENOVATION PLANT
MONTHLY TABULATION OF FLOW AND LABORATORY DATA

DECEMBER (Month) 1968 (Year)

	DATE																														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Plant Flow, M G	1.8	1.3	1.5	1.2	1.4	1.6		1.5	1.4	1.6	1.4	1.6	0.9		1.0	1.1	0.8	1.3	1.9	1.4	1.3	1.6	1.9	2.1	1.6	2.1	2.4	2.5	2.3	2.3	2.3
Peak Flow Rate MGD	-	-	-	-	4.9	6.5	2.9	7.2	4.6	4.5	6.9	5.8	4.1	3.0	2.0	2.0	2.0	7.2	2.3	3.1	5.6	3.6	8.0	7.0	2.8	9.0	6.6	5.9	6.0	4.2	5.8
Flow Into Indian Creek Reservoir, MG	1.8	1.3	1.5	1.2	1.4	1.6		1.5	1.4	1.6	1.4	1.6	0.9		1.0	1.1	0.8	1.3	1.9	1.4	1.3	1.6	1.9	2.1	1.6	2.1	2.4	2.5	2.3	2.3	2.3
Flow From Indian Creek Reservoir, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Flow From Other Outlets, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-day BOD (mg/l)		0.6	0.5		0.1	0.0		0.6				0.2						0.8	0.2								0.5				
COD (mg/l)		11.7	9.9	9.2	7.9	6.6			11.7	8.6	10.8	7.7	4.0			6.3	6.1	6.4	4.4	6.9			4.0	4.4			2.3				13.4
Suspended Solids (mg/l)																															
M B A S (mg/l)				0.11		0.10			0.12			0.11	0.13					0.11													0.15
Turbidity, J U	1.0	1.1	1.2	1.1	1.0	0.8		0.5	0.9	0.9	0.6	0.9	1.0		0.7	1.0	1.0	0.9	0.8	0.7		1.0	0.9	0.5		0.9	1.6		1.1	1.7	
pH (pH units)	7.0	6.5	6.8	7.0	6.9	7.1		6.8	7.5	6.7	7.8	7.0	6.8		6.9	7.0	7.2	7.0				7.0	7.4	7.0		6.7	6.5		6.5	7.2	6.6
Chlorine Residual(mg/l)																															
Instantaneous	2.9	1.7	1.8	2.7	3.3	3.1		2.8	2.5	2.7	3.3	2.6	0		1.1	1.1	1.0	2.8	1.7	2.1		2.7	2.1	2.3		2.6	1.2		0.8	1.5	1.1
30 Min. Contact																															
Luther Pass Station	3.1	2.6	2.5	1.9	2.3	2.0		1.9	1.9	1.9	2.0	2.5	2.0		0.8	0.8	0.7	0.7	0.6	1.2		1.6	1.7	1.6		2.0	1.8		0.2	0.5	0.4
Coliforms (MPN/100 ml)	<2.2	<2.2	<2.2	<2.2	-	<2.2		<2.2	<2.2	<2.2	<2.2	-	<2.2		2.2	<2.2	5.1	2.2	-	<2.2	-	-	<2.2	<2.2	-	-	-		-	-	-
Nitrogen (mg/l N)																															
organic																															
ammonia																															
nitrate		0.12		0	0.09	0			0.03	0.63	0.1	0.03	0.03			0.12	0.6							0.38							
nitrite		0.01		0.01	0.01	0.01			0.01	0.02	0.01	0.03	0.02			0.01	0.29							0		0.01	0.01				
Phosphate (mg/l P)		0.52	0.52	0.46	0.46	0.28			0.13	0.05	0.01	0.02				0.15	0.12	0.08		0.10				0.07			0.03				0.15
Alkalinity (mg/l $CaCO_3$)		280		271	253	263			250	220	197	210	205			270	300	262					203	427		275	287			258	240
Hardness (mg/l $CaCO_3$)		164	160	162	162	170			134	134	98	134	116			94	132	160	44	144			96	136	200	182	180			148	148
Total Dissolved Solids(mg/l)																															
Chloride (mg/l)		26	22	21	25	24				24	27	21	24			24	23	25	14	22			45	22	23	27	31			34	34
Sulfate (mg/l)		21	25	32	32	30			30	35	28	24	24			24	21	24	21	24			26	15	17	17	26			24	24

SOUTH TAHOE PUBLIC UTILITY DISTRICT - WATER RENOVATION PLANT
MONTHL ABULATION OF FLOW AND LABORATORY DATA

JAN ...
(Month) ______ (Year)

	DATE																													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Plant Flow, M G	2.2	1.9	2.1	1.8	1.8	1.6	1.5	1.1	1.6	1.6	1.9	1.8	2.4	2.5	2.0	1.8	1.6	3.2	4.8	4.1	3.3	1.8	1.6	1.9	3.0	3.9	2.3	2.0	1.9	1.8	2.0
Peak Flow Rate MGD	4.6	4.8	3.8	3.0	3.4	3.6	2.9	7.4	1.7	5.8	3.8	3.2	8.8*	8.5*	4.1	3.0	3.3	4.5	8.2*	9.1*	7.4*	3.8	3.5	4.3	5.3	5.4	4.1	3.7	3.7	4.1	4.0
Flow Into Indian Creek Reservoir, MG	2.2	1.9	2.1	1.8	1.8	1.6	1.5	1.1	1.6	1.6	1.9	1.8	2.4	2.5	2.0	1.8	1.6	3.2	4.8	4.1	3.3	1.8	1.6	1.9	3.0	3.9	2.3	2.0	1.9	1.8	2.0
Flow From Indian Creek Reservoir, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Flow From Other Outlets, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-day BOD (mg/l)	1.6						0.6	0.9		0.2			1.3	—	3.1	2.9	1.5			1.7	3.0	2.6	0.8	2.9					0.7		0.5
COD (mg/l)		12.0	3.8			9.4	7.8		15.6	12.6			11.0	11.6	13.4	12.0	8.6			9.3	9.3	8.9	7.0	6.8			18.6	13.2		4.0	6.6
Suspended Solids (mg/l)																															
M B A S (mg/l)			0.12				0.16									0.10						0.28		0.13							0.35
Turbidity, J U	1.2	2.7	1.7		1.5	4.4	2.7	2.5				1.1					0.8		1.5	1.4	1.5	1.1	1.5	1.5		1.6	2.5	1.5	5.2	3.3	
pH (pH units)	6.7	7.2	6.4		6.5	6.5	6.8	6.4	6.9	6.8		6.9	7.0	6.7	7.2	6.7	6.8		6.7	6.5	6.5		7.0	7.1		6.8	6.8	6.7		6.8	6.9
Chlorine Residual(mg/l)																															
Instantaneous	1.8	1.4	1.3		1.9	1.7	2.0	3.1	2.3	2.1		1.3	1.8	1.6	1.0	2.0	2.4		0.8	1.0	0.9	1.6	2.7	0.0		0.9	1.4	2.7	1.6	1.6	1.5
30 Min. Contact																															
Luther Pass Station	0.0	0.0	0.6		1.1	0.9	1.1	1.2	0.8	1.1		1.0	1.1	0.9	1.0	0.6	1.4		0.8	0.0	0.0	0.9	0.0	1.8		0.7	0.4	0.9	1.2	1.5	0.9
Coliforms (MPN/100 ml)	-	-	-		<2.2	<2.2	<2.2	<2.2	-	<2.2		<2.2	<2.2	<2.2	<2.2	-	<2.2		<2.2	<2.2	<2.2	5.1		2.2		<2.2	<2.2	<2.2	<2.2	—	<0.2
Nitrogen (mg/l N)																															
organic																															
ammonia										2.7																					
nitrate										0.38			0.48	0.03		0.18	0.17			0.09	0.40	0.09	0.00	0.41							
nitrite		0.02					0.09	0.03	0.03	0.02			0.15	0.01		0.12				0.03	0.03	0.01	0.01	0.03			0.02	0.01	0.01	0.01	
Phosphate (mg/l P)		0.10	0.07			0.02	0.10	0.20	0.18	0.15			0.17	0.26	0.51	0.26	0.05			0.13	0.20	0.01	0.31	0.08			0.54	0.23	0.14	0.09	0.10
Alkalinity (mg/l $CaCO_3$)	262	271	274			295	340	255	258	252			245	218						246	231	215	277	241			195	195	254	240	166
Hardness (mg/l $CaCO_3$)	304	300	300			156	152	56	82	74			164	48	130		150			152	158	160	146	180			154	164	176	120	
Total Dissolved Solids(mg/l)																															
Chloride (mg/l)	39	43	37			49	27	24	26	24			39	42	37	33	30			35	16	12	12	18			32	29	39	39	
Sulfate (mg/l)	24	24	25			27	19	26	23	24			30	33	18	27	27			23	12	10	15	14			21	18	36	18	

* All peak flows in excess of 5.8 mgd are due to pumping of storm water by Upper Truckee Pump Station, from uncompleted, unconnected sewer system.

SOUTH TAHOE PUBLIC UTILITY DISTRICT - WATER RENOVATION PLANT
MONTHLY TABULATION OF FLOW AND LABORATORY DATA

February (Month) 1969 (Year)

	DATE																														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Plant Flow, M G	2.2	2.1	1.8	1.8	1.8	1.7	1.9	2.1	2.0	2.0	1.8	1.8	1.8	1.8	1.9	1.7	1.8	1.7	1.4	1.9	2.3	2.2	2.3	1.9	1.8	2.0	2.5	1.9			
Peak Flow Rate MGD	4.4	4.6	4.5	3.4	4.1	3.7	3.3	4.0	4.1	3.3	4.7	4.3	3.6	3.6	3.4	3.5	3.3	3.1	3.2	3.7	3.5	4.2	3.9	4.4	6.5*	6.8*	7.4*	4.6			
Flow Into Indian Creek Reservoir, MG	2.2	2.1	1.8	1.8	1.8	1.7	1.9	2.1	2.0	2.0	1.8	1.8	1.8	1.8	1.9	1.7	1.8	1.7	1.4	1.9	2.3	2.2	2.3	1.9	1.8	2.0	2.5	1.9			
Flow From Indian Creek Reservoir, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
Total Flow From Other Outlets, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
5-day BOD (mg/l)																				1.6											
COD (mg/l)			4.3	5.0	11.1	10.5					9.3	14.8	16.3	16.2			24.8				10.4			12.2	10.4	3.7	7.9	7.2			
Suspended Solids (mg/l)																															
M B A S (mg/l)												0.28	0.20						0.27	0.11						0.12		0.13			
Turbidity, J U	0.4	1.1	0.4	0.2	0.6	3.0	0.2	0.2	1.4	0.4	0.8	1.4	1.1	0.8	0.5	0.7	1.0	0.8	0.5	0.3	0.5	0.5	0.5	0.7	1.2	0.8	0.8				
pH (pH units)		6.8	6.9	6.7	7.1	6.9	6.8		7.0	6.9	6.9	6.9	7.2	6.9		6.1	6.6	6.6	6.7	7.0	6.7		7.0	6.7	6.6	7.4	6.8	6.8			
Chlorine Residual(mg/l)																															
Instantaneous		1.2	1.6	1.7	1.5	2.0	1.9		1.2	1.6	2.2	0.0	1.9	2.3		2.7	2.4	2.2			3.6		3.2	3.2	3.9	3.2	4.5	2.1			
30 Min. Contact																															
Luther Pass Station		0.5	0.7	0.8	0.8	0.6	0.7		0.9	1.0	0.8	0.0	0.0	0.0		0.8	0.4	0.5			2.7		2.0	2.3	2.3	1.9	0.0	1.8			
Coliforms (MPN/100 ml)		<2.2	<2.2	<2.2	<2.2	--	<2.2		5.1	<2.2	5.1	<2.2	-	>16		<2.2	<2.2	<2.2	<2.2	-	<2.2		<2.2	<2.2	<2.2	<2.2	-	5.1			
Nitrogen (mg/l N)																															
organic																															
ammonia																															
nitrate			0.12			0.09	0.09				0.00		0.09	0.12		0.00	0.00	0.23	0.03				0.03	0.40	0.23		0.09				
nitrite			0.0	0.03	0.14	0.00	0.01			0.02		0.01	0.02	0.01		0.01	0.01	0.01	0.01	0.01			0.09	0.05	0.01	0.01					
Phosphate (mg/l P)			0.09	0.03	0.03	0.21					0.03	0.03	0.08	0.13		0.49							0.23	0.31	0.33	0.22	0.16				
Alkalinity (mg/l CaCO$_3$)			254	160	162	231	220			190	316	276	246	304		264	252	240	215	245			250	274	294	246	242				
Hardness (mg/l CaCO$_3$)			156			168	164			78	164	160	106	54		178	98		152	166			68	96	140	142	120				
Total Dissolved Solids(mg/l)																															
Chloride (mg/l)			23	22	26	24	23			30	20	28	31	15		24	28	21	22	27			23	26	22	21	21				
Sulfate (mg/l)			18	20	18	19	18			23	23	27	28	28		43	45	49	52	54			47	40	60	43	42				

*All peak flows greater than 4.7 mgd due to test pumping at Upper Truckee Pump Station

SOUTH TAHOE PUBLIC UTILITY DISTRICT - WATER RENOVATION PLANT
MONTHLY TABULATION OF FLOW AND LABORATORY DATA

MARCH
(Month)

1969
(Year)

DATE

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Plant Flow, M G	2.1	3.8	1.9	1.3	1.8	1.7	2.1	2.0	2.0	1.8	1.6	1.7	1.6	1.9	2.1	2.1	2.1	2.1	2.0	2.0	1.9	2.2	2.2	1.9	2.2	2.0	2.3	2.3	2.7	3.0	3.0
Peak Flow Rate MGD	-	-	-	-	3.3	4.0	2.2	4.7	3.6	2.7	3.7	3.8	4.6	4.1	3.1	3.0	2.2	4.4	3.8	3.9	5.0	3.7	4.8	4.2	4.1	4.1	3.7	4.2	3.7	4.4	4.0
Flow Into Indian Creek Reservoir, MG	2.1	3.8	1.9	1.3	1.8	1.7	2.1	2.0	2.0	1.8	1.6	1.7	1.6	1.9	2.1	2.1	2.1	2.1	2.0	2.0	1.9	2.2	2.2	1.9	2.2	2.0	2.3	2.3	2.7	3.0	3.0
Flow From Indian Creek Reservoir, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Flow From Other Outlets, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-day BOD (mg/l)			1.5	1.6			0.9			1.0	0.8	1.4	1.7	0.7						0.5											0.6
COD (mg/l)			3.2	6.8	8.8		8.5			7.8	7.9	11.8	9.3	9.6			7.0	10.2	8.1	8.5	4.0			6.7	10.7	16.3	16.1	11.7			8.8
Suspended Solids (mg/l)																															
M B A S (mg/l)				0.11						0.01	0.13	0.10	0.10						0.20	0.17											
Turbidity, J U	0.6	0.4	0.3	0.3	0.3	0.4	0.5	0.4	0.5	0.3	0.3	0.3	0.3	0.3	0.4	0.8	0.1	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.9	0.4
pH (pH units)		6.6	6.7	6.7	6.9	6.9	6.9		6.8	7.0	7.2	7.3	7.5	7.7		7.4	7.0	8.0	8.3	8.2	7.5		7.2	7.2		8.5				7.2	6.9
Chlorine Residual(mg/l)																															
Instantaneous		2.9	4.4	4.7	7.6	3.0	2.0		3.6	4.5	4.0	4.3	3.5	2.4		1.8	5.1	3.1	2.2	4.7	3.4		2.5	0.8	0.9	1.0	1.4	1.6		1.2	2.5
30 Min. Contact																															
Luther Pass Station		2.2	2.3	2.3	2.3	2.8	3.7		2.0	2.2	2.2	2.1	2.1	3.1		1.8	2.8	2.0	2.1	0.9	3.3		0.9	1.2	1.0	1.0	0.9	1.6		1.0	3.6
Coliforms (MPN/100 ml)		<2.2	<2.2	<2.2	<2.2	<2.2	<2.2		<2.2	<2.2	<2.2	<2.2	<2.2	<2.2	5.1	<2.2	<2.2	<2.2	<2.2	5.1	<2.2			<2.2	<2.2	<2.2	<2.2	<2.2			2.2
Nitrogen (mg/1 N)																															
organic																															
ammonia																															
nitrate			0.09	0.00		0.09				0.32	0.38		0.22				0.6		0.38	0.48	0.38			0.22		0.4					
nitrite			0.15	0.06		0.07	0.09			0.09	0.38	0.03					0.01	0.47	0.13	0.16	0.07			0.05		0.00					
Phosphate (mg/1 P)			0.10	0.13	0.15	0.26	0.25			0.15	0.15	0.22	0.27				0.25	0.22	0.16	0.33	0.51			0.20		0.26	0.23	0.19			0.39
Alkalinity (mg/1 CaCO$_3$)			245	258	256	254	245			292	277	239	260	295			282	319	226	242	220			162	170	131					160
Hardness (mg/1 CaCO$_3$)			172	156	162	166	172			148	144	54	170	68			118	128	148	158	178			206		78	76	118			140
Total Dissolved Solids(mg/l)																															
Chloride (mg/l)			24	28	25	27	28			23	27	25	29	27			27	30	25	25	24			26	32	24	27	25			26
Sulfate (mg/l)			42	44	45	45	48			26	34	31	30	30			30	18	18	16	24			14	15	18	22	16			18

SOUTH TAHOE PUBLIC UTILITY DISTRICT - WATER RENOVATION PLANT
MONTHLY TABULATION OF FLOW AND LABORATORY DATA

APRIL (Month) 1969 (Year)

	DATE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Plant Flow, M G	3.3	2.4	2.6	2.7	3.0	2.4	2.3	2.2	2.3	2.2	2.4	2.6	2.5	2.4	2.2	2.3	2.5	2.4	2.5	2.4	2.5	2.9	3.1	3.0	2.4	3.0	2.7	2.7	2.5	2.6	
Peak Flow Rate MGD	4.0	4.6	4.8	4.7	4.7	4.6	5.0	-	-	-	4.5	4.3	4.8	4.2	3.4	5.0	5.0	3.3	4.0	3.6	3.2	3.6	3.8	3.5	3.0	3.5	3.5	3.3	3.3	3.5	
Flow Into Indian Creek Reservoir, MG	3.3	2.4	2.6	2.7	3.0	2.4	2.3	2.2	2.3	2.2	2.4	2.6	2.5	2.4	2.2	2.3	2.5	2.4	2.5	2.4	2.5	2.9	3.1	3.0	2.4	3.0	2.7	2.7	2.5	2.6	
Flow From Indian Creek Reservoir, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Total Flow From Other Outlets, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
5-day BOD (mg/l)	0.5	-	0.0	1.1		-	-	1.1	-	-	1.1		-	0.5	0.5	0.0	-	0.2		-	-	0.6	0.7	1.0	0.6		-	0.3	0.2	0.3	
COD (mg/l)	10.9	4.9	4.9	7.4			3.1	7.6	8.4	5.4	4.9			6.5	7.8	5.6	5.0	3.3					6.3	5.6	4.3			4.0	5.3	4.7	
Suspended Solids (mg/l)																															
M B A S (mg/l)		0.06							0.08	0.09				0.13		0.10	0.11						0.06	0.10						0.06	
Turbidity, J U	0.3	0.3	0.2	0.1		0.8	0.1	0.1	0.1	0.1	0.1		0.6	0.3		0.2	0.2	0.2		0.3	0.2		0.2	0.2	0.2		0.7	0.1	0.1		
pH (pH units)	6.9	7.8	7.1	7.8		6.8	7.3	6.6	8.1	8.5	7.9		7.4	7.2	8.0	7.4	7.5	6.8		7.6	7.6	8.2	7.9	7.8	7.6		7.6	8.5	7.1	8.1	
Chlorine Residual(mg/l)																															
Instantaneous	1.6	3.1	2.8	3.4		4.0	3.3	3.4	4.3	4.6	4.9		4.0	3.4	3.0	5.3	4.2	4.5		4.0	1.5	0.8	0.6	1.2	1.2		1.2	1.2		0.9	
30 Min. Contact																															
Luther Pass Station	3.4	2.0	3.4	2.4		2.2	2.9	2.0	3.3	2.8	6.4		3.1	1.6	1.7	2.0	2.8	2.1		3.5	0.5	0.5	0.4	1.0	0.9		0.7	0.8		0.5	
Coliforms (MPN/100 ml)	2.2	<2.2	<2.2	<2.2		-	<2.2	<2.2	<2.2	<2.2	<2.2		-	<2.2	<2.2	<2.2	<2.2	<2.2		-	<2.2	<2.2	<2.2	<2.2	<2.2		-	<2.2	<2.2	<2.2	
Nitrogen (mg/l N)																															
organic																															
ammonia																															
nitrate		0.63	0.79	0.8			0.63		0.79	1.3	1.0			1.8		1.6	1.7				0.63	0.9	1.3	1.8	2.7			2.1	1.0	1.1	
nitrite	0.07	0.78	0.12	0.12			0.74		0.65	0.54	0.74			0.74	0.34	0.22	0.14				0.01	0.19	0.29	0.33	0.33			0.11	0.08	0.08	
Phosphate (mg/l P)	0.47	0.47	0.49	0.22			0.21	0.16	0.24	0.15	0.13			0.46	0.39	0.26	0.37	0.49			0.26	0.17	0.20	0.05	0.03			0.12	0.04	0.05	
Alkalinity (mg/l CaCO$_3$)	142	203	190	170			267	216	218	226	236			206	193	202	216	196			234	229	217	227	228			186	242	283	
Hardness (mg/l CaCO$_3$)	120	154	166	170			160	156	150	84	160			140	132	142	144	148			70	156	152	168	168			126	170	162	
Total Dissolved Solids(mg/l)																															
Chloride (mg/l)	23	24	23	26			20	20	22	22	21			19	22	20	35	18			18	22	18	17	15			16	26	15	
Sulfate (mg/l)	20	16	16	16			26	26	18	26	20			16	18	20	18	18			21	16	18	15	22			22	16	15	

SOUTH TAHOE PUBLIC UTILITY DISTRICT - WATER RENOVATION PLAN™
MONTHLY TABULATION OF FLOW AND LABORATORY DATA

MAY (Month) — 1969 (Year)

DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Plant Flow, M G	3.0	2.4	2.9	2.5	2.4	2.0	2.0	1.9	2.2	2.1	2.0	2.2	1.0	2.3	1.9	2.0
Peak Flow Rate, MGD	3.6	3.0	3.6	3.3	-	4.7	3.6	3.0	3.2	3.2	3.0	3.1	4.3	3.8	4.7	3.4
Flow Into Indian Creek Reservoir, MG	3.0	2.4	2.9	2.5	2.4	2.0	2.0	1.9	2.2	2.1	2.0	2.2	1.0	2.3	1.9	2.0
Flow From Indian Creek Reservoir, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Flow From Other Outlets, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-day BOD (mg/l)	-	0.8		-	0.3	0.1	0.3	0.3	0.2			0.9	-	0.9	0.7	
COD (mg/l)	6.7	14.5			12.8	7.9	8.9	5.4	9.6			5.1	6.4	10.2	9.3	11.2
Suspended Solids (mg/l)																
M B A S (mg/l)	0.14							0.10						0.16	0.25	
Turbidity, J U	0.2	0.5		0.7	0.3	0.3	0.3	0.3	0.3		0.6	0.3	0.3	0.3	0.4	1.2
pH (pH units)	7.8	7.2		7.2	6.9	7.5	7.0	7.2	7.4		6.8	6.9	7.3	7.3	8.1	7.5
Chlorine Residual(mg/l)																
Instantaneous	0.8	1.3		1.3	0.9	1.0	2.0	0.9	2.0		4.0	2.7	3.5	1.3	1.3	1.4
30 Min. Contact																
Luther Pass Station	0.3	0.7		0.4	0.4	1.2	0.0	0.9	0.7		1.4	2.3	1.2	1.2	0.9	0.9
Coliforms (MPN/100 ml)	<2.2	<2.2		-	2.2	<2.2	<2.2	<2.2	<2.2		-	<2.2	<2.2	<2.2	<2.2	<2.2
Nitrogen (mg/l N)																
organic																
ammonia																
nitrate	1.75	0.63			1.0			0.23	0.02			0.12	0.12	0.12	0.28	0.19
nitrite	0.14	0.02			0.11		0.23	0.06	0.09			0.01	0.01	0.01	0.06	0.58
Phosphate (mg/l P)	0.12	-			0.07	0.11		0.20	0.21			0.13	0.12	0.13	0.09	0.26
Alkalinity (mg/l $CaCO_3$)	180	182			195	257	206	232	246			247	262	272	257	237
Hardness (mg/l $CaCO_3$)	134	128			152	156	156	148	170			144	156	152	166	130
Total Dissolved Solids(mg/l)																
Chloride (mg/l)	20	19			19	17	24	20	18			23	21	18	24	24
Sulfate (mg/l)	16	15			20	20	21	24	21			20	16	18	23	18

DATE	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Plant Flow, M G	2.1	2.0	1.9	1.7	1.9	2.0	1.8	2.0	1.8	1.9	1.7	1.8	1.9	2.4	2.4
Peak Flow Rate, MGD	3.2	3.6	3.4	4.3	3.5	3.1	3.0	3.2	3.9	3.3	3.1	3.8	4.6	4.2	2.9
Flow Into Indian Creek Reservoir, MG	2.1	2.0	1.9	1.7											
Flow From Indian Creek Reservoir, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Flow From Other Outlets, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-day BOD (mg/l)		-	0.9	0.7	0.3	0.5	0.3			1.0		0.5	–	–	
COD (mg/l)			12.2	12.1	15.4	4.7	14.6			10.5		9.9	6.8	9.9	
Suspended Solids (mg/l)															
M B A S (mg/l)					0.27	0.22									
Turbidity, J U		0.6	0.4		1.0	0.6	0.6		1.0	0.3	0.4	0.4	0.4	1.0	
pH (pH units)		7.8	7.7	7.3	8.0	8.1	7.9		7.8	6.9	7.3	7.7	7.2	7.2	
Chlorine Residual(mg/l)															
Instantaneous		0.7	1.2	0.5	0.9	0.4	1.2		0.6	1.2	1.2	1.1	1.0	0.7	
30 Min. Contact															
Luther Pass Station		0.4	0.6	0.4	0.4	0.3	0.4		0.9	0.8	0.5	0.7	0.0	0.0	
Coliforms (MPN/100 ml)		-	<2.2	<2.2	<2.2	<2.2	<2.2		-	<2.2	<2.2	<2.2	<2.2	–	
Nitrogen (mg/l N)															
organic															
ammonia															
nitrate			1.0	0.28	0.00	0.03	0.43					0.00			
nitrite			0.03	0.06	0.01	0.03	0.29					0.04			
Phosphate (mg/l P)			0.51	0.58	0.61	0.64	0.70			0.18	0.23	0.29	0.24		
Alkalinity (mg/l $CaCO_3$)			200	222	203	148	137			173	225	218	195	195	
Hardness (mg/l $CaCO_3$)			130	126	92	80	93			132	142	142	126	120	
Total Dissolved Solids(mg/l)															
Chloride (mg/l)			19	20	21	21	25			22	28	25	26	33	
Sulfate (mg/l)			27	33	35	38	24			17	19	19	18	19	

SOUTH TAHOE PUBLIC UTILITY DISTRICT - WATER RENOVATION PLANT
MONTHLY TABULATION OF FLOW AND LABORATORY DATA

JUNE (Month) 1969 (Year)

DATE

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Plant Flow, M G	2.0	2.3	2.7	2.5	2.7	2.6	2.7	2.8	2.4	2.7	2.9	2.1	2.7	3.0	3.3	2.7	2.9	2.9	2.7	2.9	3.0	2.7	2.7	2.7	3.8	2.3	2.5	2.8	2.5	2.5	
Peak Flow Rate MGD	4.9	5.0	5.0	6.6	3.8	3.8	3.8	3.7	4.4	3.7	4.9	4.7	4.6	4.6	5.7	5.6	5.4	5.0	5.7	5.5	4.9		5.7	4.6	5.4		4.2	3.8	4.2	5.0	
Flow Into Indian Creek Reservoir, MG	2.0	2.3	2.7	2.5	2.7	2.6	2.7	2.8	2.4	2.7	2.9	2.1	2.7	3.0	3.3	2.7	2.9	2.9	2.7	2.9	3.0	2.7	2.7	2.7	3.8	2.3	2.5	2.8	2.5	2.5	
Flow From Indian Creek Reservoir, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Total Flow From Other Outlets, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
5-day BOD (mg/l)				2.0	1.5	1.3				4.1	0.4	0.2	0.3			0.8	0.8	1.1		0.6		0.9	3.0	0.6		1.1				0.9	
COD (mg/l)		8.1	7.5	9.0	7.5	7.8			6.0	4.8	6.9	6.0	5.1			8.7	3.8	5.8	6.6	4.2			9.0	9.5	9.5	7.3	10.6			8.1	
Suspended Solids (mg/l)																															
M B A S (mg/l)		0.00		0.12	0.09				0.07	0.08	0.06	0.09					0.12	0.05					0.12		0.09	0.14					
Turbidity, J U	0.6	0.4	0.4	0.4	0.4	0.4		0.3	0.1	0.1	0.1	0.1	1.0		0.7	0.1	0.1	0.1	0.1	0.1		0.5	0.1	0.1	0.1	0.1	0.1		0.8	0.1	
pH (pH units)	7.5	7.9	8.0	8.4	8.1	7.0		7.8	7.7	7.5	7.4	6.7	7.6		7.1	7.6	6.7	7.2	6.8	8.1		7.0	7.6	7.3	7.9	7.7	7.5		8.8		
Chlorine Residual (mg/l)																															
Instantaneous	0.6	0.6	0.4	0.9	1.1	1.0		0.8	1.3	1.3	1.2	1.3	2.7		0.9	0.7	1.2	1.2	1.1	1.0		0.9	0.4	0.7	0.7	0.6	0.4		0.6	0.7	
30 Min. Contact																															
Luther Pass Station	0.8	0.8	0.6	0.6	0.7	0.9		0.4	0.9	0.5	0.0	0.0	0.7		0.8	0.6	0.5	0.9	0.7	0.4		0.7	0.9	0.0	0.5	0.0	0.0		1.2	0.0	
Coliforms (MPN/100 ml)		<2.2	<2.2	<2.2	2.2	<2.2			<2.2	<2.2	<2.2	<2.2	<2.2			5.1	<2.2	<2.2	<2.2	<2.2			<2.2	<2.2	<2.2	>16	<2.2			<2.2	
Nitrogen (mg/l N)																															
organic																															
ammonia																							14.1	15.3	14.5		14.7			11.5	
nitrate		0.12		0.12	0.03	1.7			0.8	0.43	0.38	1.12	0.08			0.3	4.4	3.06	2.64	0.75			0.03	0.00	0.03	0.28					
nitrite		0.00	0.05	0.05	0.04	1.25			0.22	0.12	0.1	0.02	0.4			0.2	0.32	0.31	0.3	0.08			0.02	0.00	0.01	0.19					
Phosphate (mg/l P)		0.23	0.24	0.20	0.16	0.23			0.06	0.05	0.16	0.16	0.61			0.12	0.18	0.15	0.09	0.02			0.28	0.23	0.15	0.37	0.36			0.16	
Alkalinity (mg/l $CaCO_3$)		221	203	190	149	167			222	228	222	200	211			211	161	209	203	216			229	239	252	195	190				
Hardness (mg/l $CaCO_3$)		126	124	110	74	112			152	146	150	156	136			126	132	140	142				124	146	150	114	84			76	
Total Dissolved Solids (mg/l)																															
Chloride (mg/l)		16	19	21	25	19			20	13	17	18	17			13	11	19	17				13	21	15	16	20			14	
Sulfate (mg/l)		26	28	23	17	21			16	15	15	15	18			24	20	18	18				18	18	18	18	21			20	

SOUTH TAHOE PUBLIC UTILITY DISTRICT - WATER RENOVATION PLANT
MONTHLY TABULATION OF FLOW AND LABO 'ORY DATA

JULY (Month) 1969 (Year)

	DATE																														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Plant Flow, M G	2.2	2.7	2.6	2.6	2.8	2.6	2.3	2.4	2.4	2.8	2.4	2.2	2.3	2.2	2.3	2.4	2.3	2.5	2.3	2.6	2.2	2.3	2.6	2.3	2.4	2.4	2.5	2.4	2.6	2.5	2.5
Peak Flow Rate MGD	4.2	4.4	5.3	5.3	6.6	6.1	5.5	4.9	5.7	6.4	5.3	4.8	4.8	6.4	5.6	5.0	5.0	6.9	5.0	6.0	5.1	5.1	8.6	5.7	5.1	5.3	6.2	6.2	6.3	5.1	5.6
Flow Into Indian Creek Reservoir, MG	2.2	2.7	2.6	2.6	2.8	2.6	2.3	2.4	2.4	2.8	2.4	2.2	2.3	2.2	2.3	2.4	2.3	2.5	2.3	2.6	2.2	2.3	2.6	2.3	2.4	2.4	2.5	2.4	2.6	2.5	2.5
Flow From Indian Creek Reservoir, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Flow From Other Outlets, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-day BOD (mg/l)	0.9	0.7	0.6	1.8						0.8	0.7																			0.4	
COD (mg/l)	5.6	13.7	12.6	11.8			14.9	15.7	16.5	14.9	14.1			18.9	17.7	14.0	13.3	12.5				7.8	8.5	7.4	5.3			4.1	3.5	6.7	4.6
Suspended Solids (mg/l)																															
M B A S (mg/l)							0.19	0.21	0.07	0.23						0.19	0.19														0.13
Turbidity, J U	0.1	0.4	0.1	0.6		0.9	0.3	0.3	0.3	0.3	0.3		0.9	1.0	0.7	0.4		0.2		0.8	0.1	0.1	0.1	0.1			0.4	0.1	0.1		0.2
pH (pH units)	7.9	7.7	8.1	6.9		8.4	8.3	8.8	8.4	8.5	9.4		8.1		6.9	6.6	7.2	7.2		7.7	7.4	6.9	7.0	7.1	6.8		7.4	6.9	7.0	6.6	7.0
Chlorine Residual(mg/l)																															
Instantaneous	0.7	2.7	1.7	1.2		0.4	0.7	0.6	1.2	1.2	1.2		0.5	3.0	2.0	1.7	1.2	0.7		0.5	0.8	1.2	1.2	1.2	0.9		1.4	2.0	1.6	2.0	1.7
30 Min. Contact																															
Luther Pass Station	0.0	0.0	0.0	0.44		0.0	0.0	0.0	0.0	0.53	2.1		0.4	1.2	0.0	0.0	0.4	0.0		0.8	0.7	0.5	0.5	1.0	0.8		0.9	1.2	1.2	0.0	1.2
Coliforms (MPN/100 ml)	<2.2	<2.2	<2.2	<2.2		-	<2.2	<2.2	<2.2	<2.2	<2.2		-	5.1	<2.2	5.1	<2.2	2.2		-	-	2.2	<2.2	<2.2	<2.2		-	2.2	<2.2	<2.2	<2.2
Nitrogen (mg/l N)																															
organic																															
ammonia	11.1	11.5	12.3								13.4																				
nitrate	0.45	0.52	0.52				0.38	1.5	2.4	0.52	0.52				3.85	5.0	5.5	5.5							2.9					0.44	6.7
nitrite	0.96	2.64	2.05				0.09	0.62	0.62	5.50	5.50				5.0	0.6	0.5	0.5							5.5					5.5	0.5
Phosphate (mg/l P)	0.07	0.08	0.08	0.11			0.29	0.20	0.09	0.10	0.11			0.55	0.62	1.14	0.89	0.50				0.15	0.10	0.05	0.16			0.05	0.00	0.09	0.29
Alkalinity (mg/l $CaCO_3$)	142	144	149				176		132	102					195	231	187	173				243	235	198	165			120	131	194	205
Hardness (mg/l $CaCO_3$)	64	108	64	66			68	56	58	54	38			126	142	148	148	144				166	164	150	126			158	90	160	130
Total Dissolved Solids(mg/l)																															
Chloride (mg/l)	20	21	21	20			22	20	21	21	18			22	21	17	30	20			25	17	27	27	25			25	20		19
Sulfate (mg/l)	23	23	26	21			26	26	17	17	26			33	36	48	38	27			31	31	30	28	23			37	23	19	19

SOUTH TAHOE PUBLIC UTILITY DISTRICT - WATER RE''OVATION PLANT
MONTHLY TABULATION OF FLOW AND LABORA' .RY DATA

AUGUST (Month) 1969 (Year)

	DATE																														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Plant Flow, M G	2.5	2.8	2.7	2.6	2.8	2.7	2.6	2.7	2.7	2.7	2.6	2.6	2.7	2.8	2.6	3.0	2.8	2.1	2.8	2.9	2.8	2.7	2.7	2.7	2.5	2.8	1.9	2.5	2.6	2.7	2.7
Peak Flow Rate MGD	5.1	5.6	6.2	6.3	6.6	5.4	5.3	6.1	6.7	6.0	6.2	5.5	6.3	6.9	5.8	5.8	6.3	5.7	6.6	6.2	5.5	6.2	7.1	6.6	6.9	6.3	7.1	5.9	6.2	6.2	7.1
Flow Into Indian Creek Reservoir, MG	2.5	2.8	2.7	2.6	2.8	2.7	2.6	2.7	2.7	2.7	2.6	2.6	2.7	2.8	2.6	3.0	2.8	2.1	2.8	2.9	2.8	2.7	2.7	2.7	2.5	2.8	1.9	2.5	2.6	2.7	2.7
Flow From Indian Creek Reservoir, MG	0	0	0	0	0	0	0	0	0	0	0	0	6.6	9.6	9.3	9.0	3.8	0	0	0	0	0	0	0	0	6.8	11.0	10.7	10.5	10.3	10.2
Total Flow From Other Outlets, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-day BOD (mg/l)							0.8	0.2			0.5	1.0	4.9																		
COD (mg/l)	6.4			6.0	3.9	6.2	4.0	3.9			7.6	7.4	13.0	11.8	10.7			11.1	16.2	11.2	13.0	10.0		6.3	12.9	7.2	7.6	3.2			6.3
Suspended Solids (mg/l)																															
M B A S (mg/l)	0.06			0.10								0.10	0.15	0.23	0.27											0.01					
Turbidity, J U	0.4		0.5	0.1	0.1	0.3	0.2	0.3		0.6	0.2	0.2	0.2	0.3	0.4		0.6	0.2	0.4	0.4	0.2			0.8	0.2	0.2	0.1	0.1			0.1
pH (pH units)	8.1		7.1	7.3	6.9	7.0	7.0	7.2		7.2	7.1	6.7	7.1	7.2	7.3		6.7	6.8	7.0	7.2	7.4	7.1		6.5	6.9	7.5					7.3
Chlorine Residual(mg/l)																															
Instantaneous	1.6		1.8	1.4	1.5	1.4	1.2	1.5		1.4	1.5	1.6	0.6	1.2	1.4		0.9	3.8	2.0	1.1	1.5	1.6		1.3	1.6	1.6	1.7	1.1			2.3
30 Min. Contact																															
Luther Pass Station	1.4		1.6	1.2	0.0	1.2	0.0	0.0		0.8	0.4	0.4	0.0	0.0	0.0		0.0	0.4	0.5	0.5	0.4	0.4		0.6	0.6	0.7	1.0	1.0			0.9
Coliforms (MPN/100 ml)	<2.2			<2.2	<2.2	<2.2	<2.2	<2.2			<2.2	<2.2	<2.2	5.1	<2.2			<2.2	<2.2	<2.2	<2.2	<2.2			<2.2	<2.2	<2.2	<2.2			<2.2
Nitrogen (mg/l N)																															
organic																															
ammonia											15.7																				
nitrate	7.6			7.8	4.8			3.8			1.8	0.00	0.38	0.1	1.8			1.0			2.9	0.1		1.98	0.8	0.06	0.12	1.62			
nitrite	0.46			0.12	0.01	0.05	0.05	0.4			0.3	0.00	0.01	0.04	0.05			0.02	0.02			2.80		0.21	0.05	0.23	0.02	0.06			
Phosphate (mg/l P)	0.02			0.09	0.03	0.09	0.20				0.9	0.07	0.10	0.20	0.01			0.06	0.05	0.05	0.15	0.03		0.05	0.05	0.12	0.00	0.08			0.09
Alkalinity (mg/l $CaCO_3$)	201			192	182	210	178	232			216	234	242	247	240			220	210	190	188	185		218	236	236					229
Hardness (mg/l $CaCO_3$)	134			146	146	126	130	146			136	148	146	150	150			148	154	150	136	120			150	140	136	130			134
Total Dissolved Solids(mg/l)																															
Chloride (mg/l)	20			25	17	20	23	25			27	26	24	21	23			21	26	26	27	28				26	18	27			21
Sulfate (mg/l)	24			22	40	18	16	15			20	20	22	26	26			20	54	52	56	41			30	38	23	24			24

SOUTH TAHOE PUBLIC UTILITY DISTRICT - WATER RENOVATION PLANT
' NTHLY TABULATION OF FLOW AND LABORAT RY DATA

September (Month) 1969 (Year)

	DATE																														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Plant Flow, M G	2.4	2.3	2.6	2.4	2.3	2.5	2.3	2.2	2.4	1.8	1.9	1.9	2.2	2.1	1.9	2.1	2.0	1.8	2.2	2.3	2.2	2.1	1.8	1.8	2.1	2.1	1.9	2.0	1.8	1.8	
Peak Flow Rate MGD	7.4	6.1	6.1	6.3	6.3	6.1	6.1	5.6	6.4	5.9	5.2	5.7	5.7	5.3	4.7	5.7	5.6	5.1	5.1	5.3	4.1	5.9	5.6	6.3	5.3	4.8	5.5	5.4	5.2	3.9	
Flow Into Indian Creek Reservoir, MG	2.4	2.3	2.6	2.4	2.3	2.5	2.3	2.2	2.4	1.8	1.9	1.9	2.2	2.1	1.9	2.1	2.0	1.8	2.2	2.3	2.2	2.1	1.8	1.8	2.1	2.1	1.9	2.0	1.8	1.8	
Flow From Indian Creek Reservoir, MG	4.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.2	8.3	8.3	8.3	8.3	8.3	8.3	3.1	0	0	0	0	0	0	0	
Total Flow From Other Outlets, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
5-day BOD (mg/l)	-	-	0.8	-			0.3	0.2	-	-	-	-			1.1	0.3	1.7	0.3	0.3		1.7	2.8	3.8	1.8	1.4	1.4		0.7	1.4		
COD (mg/l)	9.0	-	6.1	8.4				7.2	7.2	8.3	4.3			6.1	7.8	8.2	8.1	6.1					12.0		0.9			10.2	14.2	14.2	
Suspended Solids (mg/l)																															
M B A S (mg/l)																0.00						0.04	0.02		0.11			.014	.012		
Turbidity, J U	0.2	0.2	0.2				0.1	0.1	0.1	0.1	0.4			0.1	0.1	0.1	0.1	0.1					0.3		0.2			0.2	0.3	0.2	
pH (pH units)	7.0	6.9	6.8	6.9			7.1	7.1	7.3	7.1	7.0			6.8	7.2	6.8	7.0	7.0			6.8		6.9					7.0	7.1	7.4	
Chlorine Residual(mg/l)																															
Instantaneous	1.8	1.7	2.2	0.2			2.8	2.1		2.2	1.7			1.8		2.1	2.4	2.5			1.1		2.2	1.9	1.7			1.7	1.7	1.7	
30 Min. Contact																															
Luther Pass Station	1.2	1.2	0.6	0.4			1.6	1.9		1.8	2.6			1.0		1.5	1.9	2.0			1.9		0.8	1.1	1.2			1.1	0.8	1.1	
Coliforms (MPN/100 ml) *	-	<2.2	<2.2	<2.2			-	<2.2	<2.2	<2.2	<2.2	-		-	<2.2	<2.2	<2.2	<2.2			-	<2.2	<2.2	<2.2	<2.2			-	<2.2	<2.2	
Nitrogen (mg/l N)																															
organic																															
ammonia									10.7												17.9	16.5								11.5	
nitrate	2.2	1.9	1.1	0.9			1.0	1.8		3.3	2.4			0.2	0.0	0.7	0.4	0.1			0.2	0.4									
nitrite	0.02	0.26	0.05	0.05			0.05	0.11		0.30	0.18			0.14	0.10	0.06	0.20	1.44			1.98	0.05								0.10	
Phosphate (mg/l P)	0.15		0.15					0.05	0.05	0.08	0.24			0.06	-	0.04	0.12	0.01					0.08		0.00			0.06	0.08	0.09	
Alkalinity (mg/l $CaCO_3$)	186	193	210	192			192	192	250	191	163				120	210	215	224			210							220	196	239	
Hardness (mg/l $CaCO_3$)	130	136	136	126			136	128	136	144	128			152	118	168	172	160			160	156	174	158	148			128		128	
Total Dissolved Solids(mg/l)																														320	
Chloride (mg/l)	26	28	26	27			23	26	17	23	26			24	24	21	22	23			60	27	27	28	26			23	24		
Sulfate (mg/l)	21	20	33	23			20	22	21	27	26			30	20	23	26	18			52	48	56	43	35			23	32		

* All bacteriological samples examined in September were free of Coliform organisms.

SOUTH TAHOE PUBLIC UTILITY DISTRICT - WATER RENOVATION PLANT
MONTHLY TABULATION OF FLOW AND LABORATORY DATA

OCTOBER (Mont) 1969 (Year)

	DATE																														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Plant Flow, M G	1.8	1.5	2.8	1.8	2.0	2.0	1.7	1.8	1.8	1.7	1.9	1.7	1.7	1.6	2.2	1.9	1.9	2.0	2.0	1.8	1.6	1.7	1.7	1.7	2.0	1.9	1.5	1.6	1.9	1.6	1.6
Peak Flow Rate MGD	5.0	4.0	4.9	5.6	6.0	4.9	4.6	5.7	5.1	5.0	5.4	5.1	4.6	4.7	4.9	5.0	4.5	4.6	5.1	4.3	4.3	4.6	4.0	4.0	4.7	5.0	3.7	3.3	3.3	3.5	4.0
Flow Into Indian Creek Reservoir, MG	1.8	1.5	2.8	1.8	2.0	2.0	1.7	1.8	1.8	1.7	1.9	1.7	1.7	1.6	2.2	1.9	1.9	2.0	2.0	1.8	1.6	1.7	1.7	1.7	2.0	1.9	1.5	1.6	1.9	1.6	1.6
Flow From Indian Creek Reservoir, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Flow From Other Outlets, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-day BOD (mg/l)														0.1		0.9			0.6							1.4		1.3		1.2	
COD (mg/l)	12.5	12.8			9.9	6.1	3.5	5.3	1.9				7.6	0.6	2.6	1.2			3.9	4.9	2.7	1.8	3.0			4.6	3.2	11.9	1.7	7.8	
Suspended Solids (mg/l)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M B A S (mg/l)						0.08							0.01		0.07					0.11		0.09					0.20	0.20	0.19		
Turbidity, J U	0.1	0.1			0.2	0.3	0.2	0.1	0.1			0.1	0.1	0.1	0.1	0.1			0.3	0.2	0.1	0.2	0.2			0.5	0.4	0.2	0.3	0.8	
pH (pH units)	7.1	7.0			7.1	7.2		7.0	6.9			8.1	7.2	7.2	7.2	7.0			7.1	6.7	7.3	7.0	7.4			7.1	7.2	7.0	6.7	7.0	
Chlorine Residual(mg/l)																															
Instantaneous	1.8	2.2			1.2	1.2	2.1	2.5	2.4			2.1	1.9	1.7	3.4	2.5			2.8	2.9	2.8	3.2	2.9			2.8	2.3	3.7	2.2	1.8	
30 Min. Contact																															
Luther Pass Station	1.2	1.2			1.4	1.2	1.5	1.6	1.9			1.9	0.0	1.5	0.0	0.0			2.2	2.1	2.4	2.0	2.5			2.1	2.0	0.0	0.4	2.4	
Coliforms (MPN/100 ml)	<2.0	<2.0	<2.0	8.8	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Nitrogen (mg/l N)																															
organic																															
ammonia	14.3	12.3				15.1	17.4	16.4	10.9				16.8	17.4	16.3	14.6			11.1	16.7		15.1	19.8			16.2	16.0	18.6	18.3	18.3	
nitrate						0.5			0.2			0.3	0.1	1.0	1.3				0.1	0.1	2.32	1.5	1.4			1.1	1.6	1.9	2.4	1.3	
nitrite						0.02			0.01			0.33	0.01	0.39	0.17	0.16			1.58	0.24	0.25	0.27	0.35				0.02	0.14	0.12	0.14	
Phosphate (mg/l P)	0.01	0.09			0.11	0.29	0.21	0.19					0.12	0.14	0.12	0.12			0.16	0.24	0.11	0.15	0.11			0.12	0.11	0.01	0.13	0.15	
Alkalinity (mg/l $CaCO_3$)	430	415			214	356		220	228			249	251	277	250	261			234	248	250	261	276			246	223	250	268	255	
Hardness (mg/l $CaCO_3$)		152			126		108		142			144		156		150			158		168		148			152		176		158	
Total Dissolved Solids(mg/l)	250	340				264	330	330	330			368	360	350	366	340										170	290	310	370	450	
Chloride (mg/l)	26					22		23					20		20					22		23					28		24		
Sulfate (mg/l)	26					18		21					18		18					12		18					23	23	29	21	

SOUTH TAHOE PUBLIC UTILITY DISTRICT - WATE ENOVATION PLANT
MONTHLY TABULATION OF FLOW AND LAB TORY DATA

NOVEMBER (Month) 1969 (Year)

	DATE 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Plant Flow, M G	1.7	1.7	1.7	1.5	1.6	1.7	1.6	1.8	1.9	1.7	1.6	1.7	1.7	1.7	1.9	1.8	1.6	1.6	1.1	1.4	1.7	1.4	1.7	1.7	1.5	1.7	1.2	2.0	1.9	2.0	
Peak Flow Rate MGD	6.2	4.3	4.1	4.4	4.6	3.8	4.0	5.0	5.7	4.7	5.9	4.6	4.5	5.7	5.1	5.5	4.9	4.4	4.9	5.1	4.5	4.8	5.0	4.9	4.2	4.3	4.2	4.4	4.8	5.2	
Flow Into Indian Creek Reservoir, MG	1.7	1.7	1.7	1.5	1.6	1.7	1.6	1.8	1.9	1.7	1.6	1.7	1.7	1.7	1.9	1.8	1.6	1.6	1.1	1.4	1.7	1.4	1.7	1.7	1.5	1.7	1.7	2.0	1.9	2.0	
Flow From Indian Creek Reservoir, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Total Flow From Other Outlets, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
5-day BOD (mg/l)					2.9	0.8	0.8		3.9							2.5							1.0		2.2					0.4	
COD (mg/l)		4.8	1.7	2.5	6.4	5.4			15.4	21.7	14.3	9.2	9.9			9.3	13.3	7.8	9.0	4.2			10.4	4.8	9.5	9.2	7.8			5.9	
Suspended Solids (mg/l)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
M B A S (mg/l)			0.08		0.13					0.19		0.39					0.35														
Turbidity, J U		0.3	0.5	0.3	0.4	0.4			1.3							0.4		0.4	0.4				0.7	0.5		0.4	0.3			0.3	
pH (pH units)		7.1	8.3	8.4	6.9	7.6			6.6	7.6	7.0	6.9	7.5			7.3	6.7	7.0	6.8				7.4	8.7	7.6		7.2			7.1	
Chlorine Residual(mg/l)																															
Instantaneous		2.3		2.1	1.6	0.9			2.2	2.3	2.4	3.2	6.0			2.0	4.7	2.9	4.3	4.1			2.9	2.8	3.2	3.0				3.6	
30 Min. Contact																															
Luther Pass Station		1.9		2.0	0.0	1.9			0.0	1.2	1.3	1.1	0.3			1.9	0.0	0.3	1.9	2.7			1.9	2.0	0.0	1.9				1.7	
Coliforms (MPN/100 ml)	<2.0	<2.2	<2.2	<2.2	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	
Nitrogen (mg/l N)																															
organic																															
ammonia		15.3	12.4	18.3	15.9	13.2				16.8	14.4	22.2	6.0			15.7	17.9	18.0	19.2				17.4	19.8	22.0		20.1			22.4	
nitrate		1.6	1.8	2.2	3.9	3.7			0.4	2.1	0.0	0.2	0.0			0.2	1.4						0.1	0.4	0.0		0.0			1.1	
nitrite		0.12	0.09	0.34	0.23	0.36			0.01	0.01		0.01	0.02			0.07	0.27						0.02	0.07	0.03		0.23			0.01	
Phosphate (mg/l P)		0.02	0.04	0.06	0.04	0.06			0.04	0.01	0.03	0.09	0			0.08	0.01	0.05	0.07	0.03			0.20	0.09	0.27	0.20	0.14			0.12	
Alkalinity (mg/l $CaCO_3$)		234	250	261	290	270			206	227	247	205	215			232	217	175	210				223	258	217		220			220	
Hardness (mg/l $CaCO_3$)		168		170		144			160		162		158			148		156		148					146		148			134	
Total Dissolved Solids(mg/l)		410	390	390	520					380	350	340	416			340	360	340	360				152	350	340	330	320			300	
Chloride (mg/l)			31		28					24		26					27		28					25		22					
Sulfate (mg/l)			38		33					55		56					39		41					48		43					

SOUTH TAHOE PUBLIC UTILITY DISTRICT - WATER RENOVATION PLANT
MONTHLY TABULATION OF FLOW AND LABC TORY DATA

DECEMBER (Month) 1969 (Year)

	DATE																														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Plant Flow, M G	1.7	1.5	1.5	1.3	1.6	1.7	1.5	1.5	1.5	1.6	1.7	1.7	2.0	1.8	1.8	1.5	.4	1.5	2.1	2.7	3.0	2.3	2.3	3.4	3.2	2.9	2.8	2.4	2.7	2.1	3.0
Peak Flow Rate MGD	3.9	3.7	3.8	3.8	3.7	3.9	3.6	3.8	3.4	3.4	3.7	3.3	3.4	3.2	3.3	2.9	3.2	3.1	5.5	6.0	6.5	5.3	5.0	7.1	7.5	6.9	7.4	6.9	6.7	6.5	6.9
Flow Into Indian Creek Reservoir, MG	1.7	1.5	1.5	1.3	1.6	1.7	1.5	1.5	1.5	1.7	1.7	1.8	2.0	1.8	1.8	1.6	3.2	3.1	5.5	6.0	6.5	5.3	5.0	7.1	7.5	6.9	7.4	6.9	6.7	6.5	6.9
Flow From Indian Creek Reservoir, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Flow From Other Outlets, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-day BOD (mg/l)		0.3		0.2			0.6		0.4		0.5					3.1						6.7	1.8								
COD (mg/l)	8.1	8.9	10.4	8.9			9.7	7.6	5.4	6.2	11.3			5.9	9.4	9.1	2.9	11.5			5.4	5.9	8.8	10.9	10.9			15.9	24.0	18.1	
Suspended Solids (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
M B A S (mg/l)	0.00							0.00		0.00					0.10							0.13							0.19		
Turbidity, J U	1.4	1.0	0.8	1.0			0.3	0.3	0.3	0.3	0.3			0.3	0.3	0.3	0.3	0.3			0.3	0.6	0.5	1.5	0.6			0.5		1.0	1.0
pH (pH units)	6.6	7.8	7.4	7.9			7.6	7.8	7.5	6.8	7.1			7.2	7.2	6.8	7.2	7.2			8.3	7.2	7.1	7.5	7.1			7.1	7.4	9.0	7.3
Chlorine Residual(mg/l)																															
Instantaneous	4.4	0.7	1.9	2.7			2.0	3.5	3.1	3.8	2.4			2.1	2.6	3.3	3.3	2.4			2.3	1.6	1.7	3.1	2.7			1.9	4.7	2.3	3.8
30 Min. Contact																															
Luther Pass Station	2.4	2.3	1.3	1.0			2.3	2.0	0.0	2.7	2.8			1.0	2.2	1.9	1.9	1.7			2.7	1.9	1.4	2.2	2.6			2.1	0.9	0.0	0.0
Coliforms (MPN/100 ml)	<2.0	<2.0	2.2	5.0	<2.0	2.2	2.2		<2.0	2.2	<2.0	2.1	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Nitrogen (mg/l N)																															
organic																															
ammonia	22.3	19.2	18.3	16.8			16.8	16.8	17.8	18.9	18.2			22.0	20.7	22.6	22.6	21.2			13.5	15.0	14.5	16.1	13.0			21.1	25.4	27.1	27.1
nitrate	0.9	1.2	1.0				0.1	0.2	0.3	0.1	0.0			0.5	0.1	0.0	0.1	0.2			0.5	0.0	0.5	0.3	0.4			0.2	0.0	0.0	0.5
nitrite	0.01	0.12	0.23				0.04	0.05	0.02	0.03	0.02			0.10	0.05	0.06	0.06	0.05			0.06	0.03	0.16	0.11	0.07			0.00	0.01	0.01	0.01
Phosphate (mg/l P)	0.13	0.63	0.68	0.40			0.11	0.02	0.20	0.02	0.13			0.12	0.20	0.13	0.16	0.06			0.16	0.05	0.06		0.12			0.09	0.15	0.04	
Alkalinity (mg/l $CaCO_3$)	230	159	195	181			197	220	203	192	156			230	256	276	275	293			200	204	195	202	175			223	264	227	195
Hardness (mg/l $CaCO_3$)		114		138			150		136		142			156	172	164		168			168	178	174		156			162		168	
Total Dissolved Solids(mg/l)	290	280	320	350			360	300	290	300	320			340	370	380	390						294	320	220			340	360		
Chloride (mg/l)	25		26					26		28							24							21					25		26
Sulfate (mg/l)	32		41					37		31							30							38					52		31

SOUTH TAHOE PUBLIC UTILITY DISTRICT - WATER RENOVATION PLANT
MONTHLY TABULATION OF FLOW AND LABORATORY DATA

JANUARY (Month) 1970 (Year)

DATE

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Plant Flow, M G	3.0	2.9	2.6	2.3	1.8	1.8	1.9	1.7	2.6	2.4	2.3	1.9	2.2	3.5	3.4	5.4	3.1	3.0	3.0	3.1	4.6	3.3	3.3	3.1	2.9	2.8	3.1	2.5	2.4	2.4	2.6
Peak Flow Rate MGD	5.6	5.5	6.5	6.1	5.4	5.1	4.9	5.1	5.6	6.2	6.8	6.0	6.0	10.0	7.1	10.0	6.5	7.4	7.8	5.3	8.0	8.1	6.2	6.8	6.1	5.9	6.1	7.0	5.8	5.9	6.7
Flow Into Indian Creek Reservoir, MG	3.0	2.9	2.6	2.3	1.8	1.8	1.9	1.7	2.6	2.4	2.3	1.9	2.2	2.5	3.4	5.4	3.1	3.0	3.0	3.2	4.6	3.3	3.3	3.3	3.1	2.9	2.8	3.1	2.5	2.4	2.4
Flow From Indian Creek Reservoir, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Flow From Other Outlets, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-day BOD (mg/l)	0.2														0.3							2.4			0.3				0.3		
COD (mg/l)	2.6			15.5	13.3	18.1	17.0	14.0			11.9	9.4	7.9	5.7	6.5			4.8	4.7	2.2	1.8	1.1			3.1	3.1	4.7	6.5	3.1		
Suspended Solids (mg/l)																															
M B A S (mg/l)																			0.09		0.07										
Turbidity, J U	0.8			0.8	1.8	1.0	1.0	1.0				1.0	0.8	1.0	0.5			0.7	0.3	0.3	0.3	0.3			0.3	0.3	0.3	0.3			
pH (pH units)	7.9				7.3	8.2	8.4	8.0				6.9	6.9	6.9	6.8			6.9	7.0	7.3	7.2	7.1			7.2	7.2	7.6	7.4	7.8		
Chlorine Residual(mg/l)																															
Instantaneous	3.4			2.5	1.6	2.2	4.4	2.8			3.8	3.3	2.2	3.5	2.3			4.4	3.6	2.8	0.4	2.0			3.6	4.1	6.0	2.7			
30 Min. Contact																															
Luther Pass Station	1.8			2.5	2.7	1.2	1.4	1.9			1.9	2.4	0.4	2.0	0.0			2.3	3.0	2.7	1.5	1.3			2.6	2.6	4.7	2.8			
Coliforms (MPN/100 ml)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	2.2	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Nitrogen (mg/l N)																															
organic																															
ammonia	23.8			20.0	25.6	23.7	19.5	17.5			16.4		18.1	16.9	14.0			10.8		10.7	10.7	8.6			13.5	18.2	12.9	14.7	15.8		
nitrate	0.5			0.1	0.0	0.3	0.2	1.1				0.6		0.7	0.4			0.8	1.0	0.8		0.6			1.1		0.0	0.3	1.1		
nitrite	0.08			0.00	0.58	0.06	0.52	0.32				0.04		0.05	0.01			0.02	0.04	0.02	0.02	0.01			0.03		0.48	0.01	0.10		
Phosphate (mg/l P)	0.06			0.22	0.24	0.63	0.52	0.51			0.09	0.39	0.75	0.10	0.08			0.73	0.07	0.12	0.12	0.14			0.06	0.28	0.46	0.19	0.08		
Alkalinity (mg/l CaCO$_3$)	228				233	185	190	222				213	195	178	182			159	166	184	176	191			190	185	205	199	214		
Hardness (mg/l CaCO$_3$)	150			156		106		152			162		150		166			164		160		156			150		118				
Total Dissolved Solids(mg/l)				300	280	320		320				300	298																		
Chloride (mg/l)					27		33					24		23					15		16					19		24			
Sulfate (mg/l)					33		34					27		36					19		27					22		20			

SOUTH TAHOE PUBLIC UTILITY DISTRICT - WATER RENOVATION PLANT
MONTHLY TABULATION OF FLOW AND LABO. ·ORY DATA

FEBRUARY (Month) 1970 (Year)

	DATE																														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Plant Flow, M G	2.5	2.4	2.1	2.3	1.6	2.5	3.2	2.5	2.1	2.1	2.3	2.2	2.3	2.6	2.3	2.3	2.1	2.1	2.1	2.1	2.8	2.9	3.0	2.2	2.2	2.2	2.3	2.3			
Peak Flow Rate MGD	6.9	7.0	5.8	6.3	5.4	4.8	5.1	5.4	4.6	5.5	5.2	5.9	5.0	5.0	6.4	5.2	4.8	5.6	6.3	4.3	5.8	7.1	6.7	5.5	5.8	4.9	5.2	5.6			
Flow Into Indian Creek Reservoir, MG	2.5	2.4	2.1	2.3	1.6	2.5	3.2	2.5	2.1	2.1	2.3	2.2	2.3	2.6	2.3	2.3	2.1	2.1	2.1	2.2	2.8	2.9	2.9	2.2	2.2	2.2	2.3	2.3			
Flow From Indian Creek Reservoir, MG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
Total Flow From Other Outlets, MG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
5-day BOD (mg/l)	0.5		0.7		2.2			2.3				2.8														5.0					
COD (mg/l)	3.5	10.1	6.1	6.5	7.6			5.7	5.7	3.7		2.4			6.1	7.3	7.8	11.5				8.7	17.0	20.7	15.9	14.3					
Suspended Solids (mg/l)	0.0	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	0.0					
M B A S (mg/l)				0.10																			0.14								
Turbidity, J U	0.3	0.3	0.3	0.2	0.3			0.2	0.3	0.3	0.3				0.3	0.4	0.5	0.4	0.3			0.5	0.4	0.4	0.5	0.6					
pH (pH units)	7.6	7.8	7.6	7.5	8.2			8.0	7.8	7.6	7.7	7.7			7.7	7.8	8.0	7.9	7.6			7.7	7.7	7.2	7.1	7.4					
Chlorine Residual(mg/l)																															
Instantaneous	3.2	3.6	3.0	1.6	0.7			1.8	1.4	1.7	1.5	2.6			1.9	1.6	2.8	2.4	2.5			1.4	1.1	1.0	1.1	6.6					
30 Min. Contact																															
Luther Pass Station	3.8	2.1	2.0	1.2	1.4			0.6	0.5	0.6	0.8	1.1			1.5	1.5	1.0	0.7	0.0			0.0	0.7	0.4	0.3	0.0					
Coliforms (MPN/100 ml)		<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0		<2.0		<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0		<2.0	<2.0	<2.0					
Nitrogen (mg/l N)																															
organic																															
ammonia	23.0	19.2	18.1		17.2				20.0	20.5	16.8	17.5			19.1		20.9	19.5	18.6					25.4	23.2	18.0					
nitrate	1.3	1.0	0.5	0.5	0.4			0.3	0.2	0.3	0.0				1.1	0.7	0.3	0.1				0.5	0.1	0.1	0.1	0.1					
nitrite	0.02	0.03	0.04	0.02	0.00			0.03	0.03	0.03	0.01				0.01	0.05	0.05	0.04				0.02	0.01	0.02		0.03					
Phosphate (mg/l P)	0.22	0.17	0.30	0.13	0.25			0.27	0.13			0.32			0.21	0.21	0.19	0.09				0.43	0.19	0.12	0.09	0.09					
Alkalinity (mg/l $CaCO_3$)	197	215	210	195	225				225	255	205	220			135	150	215	210	195			210	237	247	242	222					
Hardness (mg/l $CaCO_3$)	166		172		176			176		176		106			138		148		108			178		158		164					
Total Dissolved Solids(mg/l)																		300							300						
Chloride (mg/l)		22		19					23		24					21		25					24		18						
Sulfate (mg/l)		16		22					16		17					17		22					31		19						

SOUTH IOE PUBLIC UTILITY DISTRICT - WATER RENOVATION PLANT
MONTHLY TABULATION OF FLOW AND LABORATORY DATA

MARCH (Month) 1970 (Year)

	DATE																														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Plant Flow, M G	2.5	2.2	2.0	2.0	2.4	2.1	2.5	2.5	2.1	2.1	1.9	2.1	2.4	3.0	2.5	2.4	2.2	2.2	2.2	2.3	2.5	2.6	2.5	2.5	2.5	2.0	2.4	2.8	2.4	2.0	2.0
Peak Flow Rate MGD	5.8	4.9	4.6	4.9	4.5	4.6	5.0	5.7	6.1	4.2	4.5	4.5	5.2	5.0	5.5	4.6	4.5	4.5	4.8	4.7	5.6	4.9	5.0	4.9	6.4	6.3	5.1	5.9	5.2	5.1	4.5
Flow Into Indian Creek Reservoir, MG	2.5	2.2	2.0	2.0	2.4	2.1	2.5	2.5	2.1	2.1	1.9	2.1	2.4	3.0	2.5	2.4	2.2	2.2	2.2	1.13	0.00	0.00	0.00	0.00	1.25	2.0	2.4	2.8	2.4	2.0	2.0
Flow From Indian Creek Reservoir, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	00	0	0
Total Flow From Other Outlets, MG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.13	2.50	2.60	2.51	2.53	1.25	0	0	0	0	0	0
5-day BOD (mg/l)	4.5		3.3		1.3					0.9	3.0	0.7	1.9	4.3	4.3	2.5	1.2	2.0	1.1	2.2	1.2	2.9									
COD (mg/l)	12.2	10.5	9.9	8.2	10.9			10.5		12.9	15.3	8.6			3.4			10.9	9.6			14.0	23.1	30.7	23.4	21.8			18.5	16.9	15.0
Suspended Solids (mg/l)	0.0	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	0.0			0.0	0.0	0.0
M B A S (mg/l)				0.24									0.11	0.25				0.20					0.53								
Turbidity, J U	0.5	0.4	0.4	0.4	0.4			0.4	0.5	0.4	0.4	0.7	0.7		0.4	0.4	0.4	0.4	0.4	0.3		0.8	1.1	0.8		0.8	0.8	0.7	0.8		
pH (pH units)	7.0	6.8	6.9	7.3	7.4			6.9	7.0	6.8	7.2	7.2	7.2	7.1	7.1	7.2	7.0	7.1	6.9	7.0		6.9	7.0	8.1	7.8	7.7	7.5	7.5	7.2	7.4	6.5
Chlorine Residual(mg/l)																															
Instantaneous	1.0	0.0	0.8	3.4	2.8			2.2	1.2	1.1		1.7			0.9	1.3	2.2	1.6	1.9			1.8	0.7	0.8	1.5	0.0			1.5	0.0	4.1
30 Min. Contact																															
Luther Pass Station	0.9	1.2	0.6	0.6	1.8			2.1	1.9	0.4		0.8	0.9		0.9	0.4	0.5	0.0	0.0	1.1		1.2	0.3	0.0	0.5	0.7	0.9		0.9	0.6	0.0
Coliforms (MPN/100 ml)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	8.8	38.0	<2.0	<2.0	<2.0	<2.0	<2.0
Nitrogen (mg/l N)																															
organic																															
ammonia	18.6	21.1	22.3	18.4	15.9			13.3	20.5	19.1		19.6				23.0	18.3	17.9	20.0			18.5	18.7	21.0	19.6	23.9			22.0	23.5	19.9
nitrate	0.2	0.2	0.3	0.2	0.2			0.3	0.4	0.4	0.4	0.4			0.2	0.1	0.1	0.1		0.0		0.2	0.1	0.1	0.2	0.1			0.0	0.0	0.0
nitrite			0.04	0.41	0.19			0.38	0.21	0.48	0.13	0.44			0.27	0.01	0.30	0.01	0.42	0.01		0.01	0.13	0.01	0.01	0.01			0.01	0.00	0.01
Phosphate (mg/l P)	0.06	0.01	0.11	0.08	0.20			0.29	0.17	0.21	0.33	0.19			0.01			0.15	0.06			0.15	0.17	0.63	0.37	0.03			0.10	0.10	0.09
Alkalinity (mg/l $CaCO_3$)	224	224	232	222				185		225	233	229	250	180	217	220	224	235	230	243		243	199	279	226	244			224	234	237
Hardness (mg/l $CaCO_3$)	184		185		172			162		166		122			158		156		170			154		102		164			152		168
Total Dissolved Solids(mg/l)												260																			
Chloride (mg/l)				23					26		28							22					26		26					29	
Sulfate (mg/l)		31		17					20		20							22							22						

SC TH TAHOE PUBLIC UTILITY DISTRICT - WATER RENOVATION PLANT
MONTHLY TABULATION OF FLOW AND LAB TORY DATA

APRIL (Month) 1970 (Year)

	DATE																														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Plant Flow, M G	2.0	2.0	2.0	2.2	2.3	2.1	2.2	1.1	2.3	2.1	1.6	2.1	2.0	2.0	2.0	2.1	2.1	2.3	2.1	2.1	2.0	2.2	2.0	2.1	2.2	2.3	2.1	2.1	2.0	2.2	
Peak Flow Rate MGD	4.8	4.6	4.4	5.3	4.8	5.1	5.4	4.4	3.8	4.7	6.0	5.5	4.6	4.5	5.2	4.2	4.8	5.1	5.7	5.0	5.0	5.2	4.2	4.6	5.3	5.2	6.1	5.9	4.5	5.6	
Flow Into Indian Creek Reservoir, MG	2.0	2.0	2.0	2.2	2.3	2.1	2.2	1.1	2.3	2.1	1.6	2.1	2.0	2.0	2.0	2.1	2.1	2.3	2.1	2.1	2.0	2.2	2.0	2.1	2.2	2.3	2.1	2.1	2.0	2.2	
Flow From Indian Creek Reservoir, MG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Total Flow From Other Outlets, MG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
5-day BOD (mg/l)	3.1		2.7									2.8		2.9		0.9			5.0				0.8					1.3			
COD (mg/l)	13.4	14.4			16.1	15.7	7.2	7.7	4.5			16.7	6.6	14.9	16.7	8.0			6.8	7.7	11.8	13.3	8.1			17.1	16.2	18.3		8.1	
Suspended Solids (mg/l)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0			0	0	0	0	0	
M B A S (mg/l)	0.35														0.14					0.35									0.25		
Turbidity, J U	0.5	0.3	0.3	0.3	0.3	0.5	1.0					0.5	0.5	0.5	0.5	0.6				0.5	0.5	0.5	0.5			0.4	0.4	0.4	0.4	0.5	
pH (pH units)	7.0	7.0	7.0	7.1	7.1	6.9	7.0	7.1	7.2			7.1	7.0	7.4	7.4	7.8			6.4	7.0	6.9	7.1	6.9			7.3	6.8	6.9	7.2	7.1	
Chlorine Residual(mg/l)																															
Instantaneous	3.1	2.8	2.4		1.8	2.0	6.1	0.7				2.6	2.7	2.8	2.3	2.4			1.7	2.8	3.0	3.9	2.4			1.9	2.6	2.3	1.6	1.0	
30 Min. Contact																															
Luther Pass Station	0.3	1.9	1.7		0.0	0.0	0.4	0.0				1.4	1.9	2.0	1.8	1.9			0.0	1.3	1.9	1.6	1.5			1.2	0.8	0.8	0.1	1.1	
Coliforms (MPN/100 ml)	24.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	
Nitrogen (mg/l N)																															
organic																															
ammonia	15.3	19.8			20.6	25.0	19.8	31.1	21.1			15.5	23.9	23.9		22.0			22.4	23.6	22.5	17.3	17.3			20.3	19.8	19.3	14.5	13.9	
nitrate	0.0											0.0	0.0	0.0	0.0	0.1			0.2	0.0	0.2	0.2	0.1			0.3	0.3	0.0		0.1	
nitrite	0.00											1.00	0.02	0.00	0.01	0.01			0.27	0.05	0.08	0.01	0.01			0.09	0.04	0.01		0.02	
Phosphate (mg/l P)	0.09	0.08			0.02	0.05	0.11	0.05	0.07			0.19	0.07	0.06	0.11	0.00			0.09	0.01		0.05				0.09	0.09	0.05	0.00		
Alkalinity (mg/l $CaCO_3$)	221	195	235	220	230	195	210	220	230			250	270	228	243	207			225	190	218	221	216			204	210	208	182	208	
Hardness (mg/l $CaCO_3$)		148			164		142		152			162		158		176			166		156		154			134				132	
Total Dissolved Solids(mg/l)																															
Chloride (mg/l)						32		29					29		30					25		26					26		29		
Sulfate (mg/l)	26					19		54							47					48		41					31		22		

SOUTH TAHOE PUBLIC UTILITY DISTRICT - WATER RENOVATION PLANT
MONTHLY TABULATION OF FLOW AND LABORATORY DATA

MAY (Month) 1970 (Year)

	DATE																														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Plant Flow, MG	2.1	2.3	2.3	2.1	2.0	2.0	2.0	1.9	2.1	2.2	2.0	2.0	1.9	2.0	2.1	2.4	3.0	2.1	2.1	2.0	2.0	2.0	2.3	2.2	2.1	2.1	2.0	2.0	2.3	2.7	2.2
Peak Flow Rate MGD	5.4	4.9	4.6	4.6	5.0	4.7	4.5	4.1	4.2	4.0	3.6	4.3	4.4	4.2	4.7	4.9	4.6	4.4	4.5	4.3	4.2	4.8	4.6	4.8	4.5	5.0	3.6	4.3	4.8	4.5	3.9
Flow Into Indian Creek Reservoir, MG	2.1	2.3	2.3	2.1	2.0	2.0	2.0	1.9	2.1	2.2	2.0	2.0	1.9	2.0	2.1	2.4	3.0	2.1	2.1	2.1	2.0	2.0	2.3	2.2	2.1	2.1	2.0	2.0	2.3	2.7	2.2
Flow From Indian Creek Reservoir, MG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Flow From Other Outlets, MG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5-day BOD (mg/l)																	4.7		1.0		4.8										
COD (mg/l)			20.7	15.3	17.2	12.6	10.4			14.4	13.8	8.4	12.6	16.8			7.6	8.1	13.4	11.7	11.2			9.8	8.4	22.7	9.3	21.8			17.5
Suspended Solids (mg/l)			0	0	0	0	0			0	0	0	0	0			0	0	0	0	0			0	0		0	0			0
M B A S (mg/l)																		0.30	0.30						0.18	0.31	0.26	0.45			0.46
Turbidity, J U			0.3	0.3	0.3	0.3	0.3			0.3	0.3	0.4	0.3	0.4			0.5	0.5	0.5		0.3			0.3	0.5	0.5	0.4	1.0			0.5
pH (pH units)			6.7	7.0	7.0	7.2	7.1			7.0	7.1	7.0	6.8	7.0			7.1	7.1	7.5	7.4	7.1			7.0	7.1	7.1	7.2	8.3			7.1
Chlorine Residual(mg/l)																															
Instantaneous			0.0	3.3	3.0	3.6	2.8			3.5	2.4	2.8	2.2	2.5			1.5	1.9	2.4	3.2	3.1			1.3	1.6	2.5		1.0			1.4
30 Min. Contact																															
Luther Pass Station			0.5	0.5	1.8	1.6	1.7			2.7	1.8	1.6	1.9	1.1			1.0	0.8	1.1	1.3	1.5			0.0	0.3	0.5		1.8			0.0
Coliforms (MPN/100 ml)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Nitrogen (mg/l N)																															
organic																															
ammonia			14.7	16.2	16.5	13.9	15.9			13.3	18.3	18.9	17.1	16.1			17.2	17.7	18.0	16.9	14.4			16.4		17.8	16.3	14.9			18.7
nitrate			0.3	0.1	0.0	0.0	0.2			0.3	0.1	0.1					0.1	0.0	0.2	0.2	0.0			1.4	0.0	0.0	0.0				
nitrite			0.05	0.03	0.02	0.09	0.04			0.10	0.05	0.15	0.0	0.03			0.04	0.01	0.01	0.01	0.01			0.01	0.01	0.01	0.01				
Phosphate (mg/l P)			0.09	0.01	0.09	0.01	0.01			0.01	0.11	0.06	0.01	0.15			0.11	0.08	0.15	0.19	0.19			0.01	0.09	0.02	0.01	0.30			0.11
Alkalinity (mg/l $CaCO_3$)			198	192	204	198	195			218	223	218	244	212			216	218	194	257	264			248	230	243	225	235			227
Hardness (mg/l $CaCO_3$)			154		160		162			182		170		168			132		154		174			160		172		154			146
Total Dissolved Solids(mg/l)																															
Chloride (mg/l)				.34		38					35		43					28		28					30		25				
Sulfate (mg/l)				42		40					44		45					44		36					36		36				

SOUTH TAHOE PUBLIC UTILITY DISTRICT - WATER RENOVATION PLANT
MONTHLY TABULATION OF FLOW AND LABORATORY DATA

JUNE (Month) 1970 (Year)

	DATE																														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Plant Flow, M G	2.1	2.1	2.1	2.1	2.1	2.3	2.3	2.2	2.5	2.4	2.2	2.5	2.6	2.5	2.4	2.7	2.2	2.6	2.5	2.7	2.7	2.8	2.9	2.6	2.7	3.1	3.1	2.5	3.2	3.0	
Peak Flow Rate MGD	3.9	4.9	3.9	3.8	4.3	4.2	3.8	4.2	4.2	4.1	3.9	4.1	4.2	4.2	6.9	4.8	4.2	4.5	4.1	4.4	5.2	4.6	6.0	5.6	5.5	5.5	6.4	6.1	5.5	5.5	
Flow Into Indian Creek Reservoir, MG	1.9	1.9	1.1	1.1	1.1	1.3	1.3	1.2	1.5	1.4	1.2	1.5	1.6	1.5	1.4	1.7	0.0	0.0	0.0	0.0	0.0	2.8	2.9	2.6	2.7	3.1	3.1	2.5	3.2	3.0	
Flow From Indian Creek Reservoir, MG	0.2	0.2	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	
Total Flow From Other Outlets, MG	0.2	0.2	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.2	2.6	2.5	2.7	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
5-day BOD (mg/l)	2.9	2.3	2.1	1.0			2.4	2.8	2.8	1.1	1.4										1.6								1.2		
COD (mg/l)	14.8	10.0	12.1	0.8			8.4	5.1	10.1	8.4				13.5	10.5	11.2	13.6	24.5			15.4	14.1	14.8	14.8	12.6			12.5	16.3	14.1	
Suspended Solids (mg/l)	0	0	0	0			0	0	0	0	0			0	0	0	0.0	0.0			0.0	0.0	0.0	0.0	0.0			0.0	0.0	0.0	
M B A S (mg/l)		0.41	0.45	0.42			0.23	0.31	0.46	0.19	0.35				0.41															0.19	
Turbidity, J U	0.5	0.5	0.5	0.5			0.4	0.5		0.5				1.0	1.0	1.0	2.0	1.0			0.5	0.7	1.0	0.7	0.5			1.0	1.0	0.5	
pH (pH units)	7.2	6.9	7.0	7.2			6.9	6.9	7.0	7.0	6.8				7.6	7.9	7.2	7.2			6.8	6.9	7.3	7.2	7.1			7.1	7.3	7.4	
Chlorine Residual(mg/l)																															
Instantaneous	2.1	5.9	4.0	2.8			2.2	1.0	0.0		3.6			3.9	3.6	6.3	4.4	2.3			1.9	1.6	2.1	1.2	1.9			3.0	1.6	1.8	
30 Min. Contact																															
Luther Pass Station	0.0	1.0	1.9	1.3			0.0	0.0	0.0		2.0			3.1	1.9	1.4	0.0	1.0			0.8	0.0	0.7	0.7	1.1			1.1	1.0	0.9	
Coliforms (MPN/100 ml)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	5.0	<2.0	<2.0	<2.0	5.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	
Nitrogen (mg/l N)																															
organic																															
ammonia	19.5	15.9	13.8	15.4			15.9	16.1	17.4		16.2			20.0	17.6	19.2	20.9	19.8			20.4	21.1	19.3	20.9	18.8			20.4	14.2		
nitrate	0.1	0.0	0.0	0.0			0.0	0.0		0.0	0.0										0.0	0.1		0.0				0.2	0.1	0.0	
nitrite	0.01	0.01	0.01	0.00			0.00	0.05		0.04	0.00										0.06	0.07	0.02	0.02				0.02	0.06	0.05	
Phosphate (mg/l P)	0.08	0.06	0.05	0.04			0.05	0.03	0.04	0.03	0.09			0.25	0.12	0.20	0.23	0.09			0.19	0.15	0.40	0.41	0.29			0.61	0.45	0.32	
Alkalinity (mg/l $CaCO_3$)	221	224	205	196			200	183	195	198	181				182	217	230	190			186	189	184	197	210			215	200	194	
Hardness (mg/l $CaCO_3$)		158		136			140		152		146			136		132		200			140		134		144			120		124	
Total Dissolved Solids(mg/l)																															
Chloride (mg/l)	28		24					31		27					32		31					23		24					23		
Sulfate (mg/l)	45		44					53		48					55		56					42		41					42		

SOUTH TAHOE PUBLIC UTILITY DISTRICT - WATER RENOVATION PLANT
MONTHLY TABULATION OF FLOW AND LABORATORY DATA

JULY (Month) 1970 (Year)

DATE

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Plant Flow, M G	2.6	2.7	2.9	3.3	2.8	2.7	2.8	2.8	2.8	2.8	2.8	2.6	2.9	2.5	2.3	2.5
Peak Flow Rate MGD	5.3	5.0	5.9	7.3	6.5	6.5	5.8	5.6	5.5	5.0	5.9	6.6	6.2	6.3	5.6	6.1
Flow Into Indian Creek Reservoir, MG	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Flow From Indian Creek Reservoir, MG	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	10.0
Total Flow From Other Outlets, MG	2.6	2.7	2.9	3.0	2.8	2.7	2.8	2.8	2.8	2.8	2.8	2.6	2.9	2.5	2.3	2.5
5-day BOD (mg/l)	1.1	0.8			3.2	0.3	1.4	0.2	4.3			0.1	0.3			
COD (mg/l)	12.2				15.9	16.7	12.9	16.6	17.8			14.8	13.2	12.6	11.8	28.7
Suspended Solids (mg/l)	0.0				0.0	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	0.0
M B A S (mg/l)	0.21	0.22			0.21	0.30	0.21	0.27				0.40	0.23	0.22	0.24	
Turbidity, J U	0.4	0.3			0.8	1.0	1.0	0.7	0.7			0.4	0.5	0.2	0.2	0.3
pH (pH units)	7.3	7.2			7.1	7.0	7.3	7.5	8.9			7.2	7.2	7.6	7.5	7.6
Chlorine Residual(mg/l)																
Instantaneous	3.0	1.9			1.9	1.8	2.0	3.6	2.1			2.7	2.1		0.6	2.3
30 Min. Contact																
Luther Pass Station	1.1	0.9			0.7	1.2	1.1	1.1	1.6			1.2	1.2		0.8	0.8
Coliforms (MPN/100 ml)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	
Nitrogen (mg/l N)																
organic																
ammonia	19.5	18.2			24.1	26.2	20.3		18.8			23.1	22.1	20.1	21.2	22.4
nitrate	0.0	0.3			0.1	0.2	0.0	0.2	0.0			0.1	0.1	0.0	0.1	
nitrite	0.03	0.02			0.01	0.01	0.01	0.02	0.01			0.02	0.03	0.02	0.11	
Phosphate (mg/l P)	0.16	0.10			0.40	0.68	0.59	0.51	0.39			0.23	0.23	0.22	0.12	0.05
Alkalinity (mg/l CaCO$_3$)	230	225			220	241	235	225	236			223	223	235	248	235
Hardness (mg/l CaCO$_3$)		142			134		148		128			124		134		126
Total Dissolved Solids(mg/l)																
Chloride (mg/l)	29					27		24					32		28	
Sulfate (mg/l)	40					48		52					40		36	

	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Plant Flow, M G	2.7	3.1	2.6	2.4	2.9	2.6	2.8	2.9	3.0	2.9	2.8	2.7	2.6	2.9	2.7
Peak Flow Rate MGD	6.2	6.9	6.5	6.2	7.8	6.8	5.8	5.8	6.9	6.6	6.9	6.9	7.6	6.7	7.7
Flow Into Indian Creek Reservoir, MG	2.7	3.1	2.6	2.4	2.9	2.6	2.8	2.9	3.0	2.9	2.8	2.7	2.6	2.9	2.7
Flow From Indian Creek Reservoir, MG	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Total Flow From Other Outlets, MG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5-day BOD (mg/l)											1.8	2.0			
COD (mg/l)			16.2	17.0	9.7	12.2	19.4			9.4	13.7	19.1	14.8	13.7	
Suspended Solids (mg/l)			0.0	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	0.0	
M B A S (mg/l)			0.40	0.22	0.12	0.20					0.17	0.17	0.11	0.08	
Turbidity, J U			0.3	0.3	0.3	0.4	0.5			0.3	1.0	0.2	0.3	0.2	
pH (pH units)			7.6	7.4	8.5	7.4	7.4				8.3	7.9	7.5	7.8	
Chlorine Residual(mg/l)															
Instantaneous			1.4	2.8	1.2	3.2	1.4			1.6	2.3	5.5	2.6	5.0	
30 Min. Contact															
Luther Pass Station			0.9	0.0	1.4	1.2	1.2			0.9	0.6	1.6	1.9	4.1	
Coliforms (MPN/100 ml)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Nitrogen (mg/l N)															
organic															
ammonia			20.1	20.3	20.3	20.2	19.2			20.4	20.1	23.1	24.3		
nitrate			0.2	0.2	0.1	0.4					0.6	0.4	0.3	0.0	
nitrite			0.13	0.05	0.35	0.11					0.00	0.03	0.07	0.03	
Phosphate (mg/l P)			0.33	0.31	0.14	0.15	0.25				0.46	0.75	0.39	0.18	
Alkalinity (mg/l CaCO$_3$)			180	232	275	255	210				145	255	245	265	
Hardness (mg/l CaCO$_3$)			74				148					132		150	
Total Dissolved Solids(mg/l)															
Chloride (mg/l)				24		27							30		
Sulfate (mg/l)				33		19					40		41		

SOUTH TAHOE PUBLIC UTILITY DISTRICT - WATER RENOVATION PLANT
MONTHLY TABULATION OF FLOW AND LABORATORY DATA

AUGUST (Month) 1970 (Year)

	DATE																														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Plant Flow, M.G.	3.0	2.9	2.7	2.8	2.9	2.9	3.0	3.2	2.0	2.8	3.1	3.1	3.1	3.3	3.2	3.0	3.0	3.1	3.1	3.2	3.3	3.1	3.0	3.4	3.1	3.1	2.9	3.0	3.2	2.8	2.7
Peak Flow Rate MGD	6.9	6.3	6.6	7.1	6.4	6.4	6.8	6.6	6.0	6.2	6.8	6.7	7.0	7.0	6.4	6.8	6.5	7.2	6.2	6.8	6.7	6.6	7.1	7.1	7.1	6.2	6.4	6.1	6.3	5.8	5.9
Flow Into Indian Creek Reservoir, MG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Flow From Indian Creek Reservoir, MG	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Total Flow From Other Outlets, MG	3.0	2.9	2.7	2.8	2.9	2.9	3.0	3.2	2.0	2.8	3.1	3.1	3.1	3.3	3.2	3,0	3.0	3.1	3.1	3.2	3.3	3.1	3.0	3.4	3.1	3.1	2.9	3.0	3.2	2.8	2.7
5-day BOD (mg/l)		0.1	3.5	1.7	1.2	3.1			0.7	0.4	0.9		0.4			0.5	0.5	0.9	1.2	1.8			1.1	0.2	0.7	0.4	0.5			1.0	0.3
COD (mg/l)		11.9	10.8	14.0	9.8	10.5			20.0	17.2	12.8	11.5	8.0			6.1	12.9	13.2	5.1	5.4			9.9	12.9	10.1	7.5	7.1			13.3	8.2
Suspended Solids (mg/l)		0.0	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	0.0			0.0	0.0
M B A S (mg/l)		0.19		0.12	0.10	0.22							0.08			0.18	0.05	0.10	0.12	0.07			0.05	0.13	0.09	0.10	0.09			0.15	
Turbidity, J U		0.3	0.3		0.3	0.3				0.4	0.3	0.3	0.3			0.2	0.3	0.3	0.3	0.3			0.3	0.3	0.3	0.3	0.2			0.2	0.1
pH (pH units)		8.3		7.3	7.5	7.8			7.7	7.4	7.3	7.6	7.5			7.2	7.4	7.5	7.7	7.8			7.6	7.5	7.4	7.1	6.8			7.4	7.3
Chlorine Residual(mg/l)																															
Instantaneous	1.9	1.8	2.7	3.3	1.9	2.4			1.6	2.3	0.9	1.9	0.0			2.0	0.8	2.4	0.4				1.6	1.2	1.5	1.9	1.6			1.9	4.3
30 Min. Contact																															
Luther Pass Station	0.0	1.5	1.8	2.1	1.5	1.4			0.9	0.9	0.7	0.9	1.0			0.5	1.3	0.8	1.1				1.3	1.0	0.9	1.0	1.2			1.2	1.3
Coliforms (MPN/100 ml)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0		<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0		<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	
Nitrogen (mg/l N)																															
organic																															
ammonia		20.6	19.0	20.4	19.5	20.2			18.9	21.2	20.5	18.4	18.0			19.6	18.8	21.0	20.1	19.6			18.6	17.4	17.9	20.0	15.1			15.3	17.7
nitrate		0.1		0.8		0.4							0.3			0.6	0.1	0.8	0.7	1.0			1.4	0.9	0.7	1.2	0.9			1.0	1.2
nitrite		0.19		0.24		0.46							0.05			0.09	0.08	0.08	0.11	0.16			0.13	0.19	0.19	0.37	0.34			0.01	0.03
Phosphate (mg/l P)		0.28	0.24	0.14	0.21	0.18			0.48	0.23	0.36	0.39	0.32			0.26	0.31	0.60	0.37	0.59			0.24	0.22	0.11	0.65	0.06			0.09	0.12
Alkalinity (mg/l $CaCO_3$)		315		252	252	192			210	250	210	228	270			260	267	234	251	267			266	246	246	220	176			236	229
Hardness (mg/l $CaCO_3$)		136		180		172			144		174		174			126		138		142			144				200			140	
Total Dissolved Solids(mg/l)																		272	318	318	388			308	324	340	376	378			
Chloride (mg/l)			29		32					24		28					29		26					29		24					24
Sulfate (mg/l)			36		34					33		34					19		31					23		55					22

SOUTH TAHOE PUBLIC UTILITY DISTRICT - WATER RENOVATION PLANT
MONTHLY TABULATION OF FLOW AND LABORATORY DATA

SEPTEMBER (Month) 1970 (Year)

DATE

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Plant Flow, M G	2.7	2.6	2.6	2.9	3.0	3.3	3.0	2.4	2.5	2.4	2.4	2.5	2.3	2.2	2.4	2.5	2.3	2.4	2.5	3.4	2.3	2.2	2.2	2.2	2.1	2.3	2.3	2.0	2.2	2.1	
Peak Flow Rate MGD	5.8	5.8	6.6	7.0	6.8	7.0	6.0	6.0	5.8	6.0	6.0	6.6	6.5	5.3	6.0	5.3	5.2	6.0	6.8	5.6	5.7	5.1	4.9	5.3	5.2	6.1	6.1	4.8	5.1	4.8	
Flow Into Indian Creek Reservoir, MG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	2.4	2.5	3.4	2.3	2.2	2.2	2.2	2.1	2.3	2.3	2.0	2.2	2.1	
Flow From Indian Creek Reservoir, MG	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	10.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.	10.	10.	10.	10.	0.0	
Total Flow From Other Outlets, MG	2.7	2.6	2.6	2.9	3.0	3.3	3.0	2.4	2.5	2.4	2.4	2.5	2.3	2.2	2.4	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
5-day BOD (mg/l)	2.0		0.6			0.8	0.3	0.8	0.2	0.7			0.9	0.5	2.2	0.7	1.1			2.1	0.5		0.5	0.6			1.4	2.6		0.6	
COD (mg/l)	9.2	7.1	10.5			9.6	7.1	9.9	10.2	10.5							9.6			7.3	9.6	9.6	7.3	12.5			9.6	10.5		9.8	
Suspended Solids (mg/l)	0.0	0.0	0.0			0.0	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	
M B A S (mg/l)	0.20	0.19	0.20			0.14	0.19	0.13	0.16	0.14			0.21	0.23	0.21	0.20	0.14			0.19	0.24	0.24	0.25	0.16			0.16	0.19	0.17	0.16	
Turbidity, J U	0.1	0.1	0.2			0.2	0.2	0.2	0.2	0.3			0.2	0.2	0.2	0.2	0.2			0.2	0.2		0.2	0.2			0.3	0.3	0.2	0.2	
pH (pH units)	7.4	7.4	7.3			7.2	7.1	7.0	7.2	7.1			7.5	7.5	7.2	7.6	7.5			7.2	7.5	7.6	6.8	7.2			7.2	7.6	8.1	8.3	
Chlorine Residual(mg/l)																															
Instantaneous	3.2	4.1	2.8			1.9	2.8	2.7		4.1			2.3	3.0	3.5	2.7	2.7			1.9	3.0	2.8	3.7	3.6	2.6		2.8	2.5	2.7	3.6	
30 Min. Contact																															
Luther Pass Station	1.3	1.3	1.2			1.2	1.2	1.6		0.0			1.9	1.8	2.6	2.5	2.1			1.9	1.5	2.0	1.8	1.9	3.0		1.4	2.7	2.0	1.6	
Coliforms (MPN/100 ml)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	8.8	<2.0	
Nitrogen (mg/l N)																															
organic																															
ammonia	19.2	18.4	15.1			16.4	18.6	18.2	12.6	15.4			15.5	17.4	16.5	14.4	16.7			16.4	16.1	17.5	14.2	13.8			18.3	17.2	18.7	16.5	
nitrate	1.3	1.3	1.1			1.7	1.5	1.3	1.6	0.6			0.5	1.0	0.1	1.5	1.6			8.6	0.4	0.9	0.7	0.9			0.5	0.3	0.4	0.0	
nitrite	0.37	0.30	0.49			0.30	0.44	0.39	0.45	0.45			0.11	0.52	0.52	0.35	0.34			0.44	0.38	0.35	0.35	0.30			0.34	0.04	0.11	0.11	
Phosphate (mg/l P)	0.08	0.06	0.04			0.06	0.00	0.13	0.19	0.09			0.06	0.05	0.00	0.00	0.02			0.07	0.04	0.04	0.07	0.01			0.06	0.19		0.20	
Alkalinity (mg/l $CaCO_3$)	239	229	220			246	265	235	244	212			215	257	235	244	225			277	258	235	224	212			205	196	204	200	
Hardness (mg/l $CaCO_3$)	148		138			138		146		126			139		150		114			138		132		122							
Total Dissolved Solids(mg/l)																													260		
Chloride (mg/l)		43					30		26					29		26					30		28					27		29	
Sulfate (mg/l)		23					22		33					33		26					52		46					36		39	

SOUTH TAHOE PUBLIC UTILITY DISTRICT - WATER RENOVATION PLANT
MONTHLY TABULATION OF FLOW AND LABORATORY DATA

OCTOBER (Month) 1970 (Year)

DATE

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Plant Flow, M.G.	2.2	2.0	2.3	2.4	1.9	2.1	2.1	2.1	2.1	2.2	2.1	2.0	2.0	2.1	1.9	2.1	2.3	2.2	1.9	2.0	2.4	2.2	2.0	2.2	2.1	1.8	1.7	2.1	1.8	1.9	1.9
Peak Flow Rate MGD	4.0	5.3	5.2	5.5	5.2	5.0	4.3	4.8	4.9	5.3	5.0	4.9	4.9	5.1	4.5	5.1	4.7	4.7	4.7	4.8	6.0	5.2	5.5	5.8	6.1	6.0	5.3	5.5	4.7	4.7	4.7
Flow Into Indian Creek Reservoir, MG	2.2	2.0	2.3	2.4	1.9	2.1	2.1	2.1	2.1	2.2	2.1	2.0	2.0	2.1	1.9	2.1	2.3	2.2	1.9	2.0	2.4	2.2	2.0	2.2	2.1	1.8	1.7	2.1	1.8	1.9	1.9
Flow From Indian Creek Reservoir, MG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Flow From Other Outlets, MG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5-day BOD (mg/l)			0.7	1.3	1.4	0.9	0.5			0.9	1.1	1.2	1.2	0.4	0.4			0.6	1.2	0.3	0.8	1.7			0.5	1.1	1.2	1.2	1.4		
COD (mg/l)			7.3		10.0	4.9	6.9	6.3			8.2	6.0	5.6	13.2	12.9			11.5	9.2	8.1	8.3	7.0			7.0	7.7	9.3	9.9	10.9		
Suspended Solids (mg/l)	0.0		0.0		0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	0.0			0.0	0.0	0.0	0.0	0.0		
M B A S (mg/l)	0.06		0.09		0.09	0.09	0.09	0.08			0.10	0.11	0.11	0.09	0.14			0.11	0.14	0.08	0.12	0.15			0.17	0.14	0.11	0.14			
Turbidity, J U			0.2		0.2	0.2	0.1	0.1			0.2	0.2	0.2	0.2	0.2			0.2	0.2	0.2	0.2	0.2			0.2	0.2	0.2	0.2	0.2		
pH (pH units)	7.1		7.5		7.5	7.3	7.2	7.5			7.5	7.5	7.6	7.5	7.4			7.3	7.4	7.3	7.3	7.2			7.2	7.1	6.9	7.1	7.2		
Chlorine Residual(mg/l)																															
Instantaneous	3.1		1.2		1.3	1.2	1.4	1.4			0.8	2.3	1.7	1.5	1.7	1.7		1.7	1.1	1.6	1.6	2.2			1.6	1.9	1.8	1.6	1.4		
30 Min. Contact																															
Luther Pass Station	1.9		0.5		0.7	0.8	0.9	1.0			1.0	1.0	1.1	0.9	1.0	1.0		1.5	0.8	0.8	0.8	0.8			0.5	1.1	1.3	1.3	1.1		
Coliforms (MPN/100 ml)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	5.0	<2.0	4.4	15.0	8.8	15.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Nitrogen (mg/l N)																															
organic																															
ammonia	15.1		17.4					19.7					17.9	13.9	17.0			13.3	17.7			14.1			16.7	16.2	16.5	16.3	14.8		
nitrate	0.5		0.3		0.3	0.6	0.8	0.9			0.9	0.5	0.8	0.5	0.4			1.0	1.0	0.7	0.7	0.1			0.6	0.6	1.3	0.8	0.7		
nitrite	0.34		0.02		0.11	0.02	0.13	0.11			0.15	0.04	0.11	0.12	0.12			0.13	0.12	0.32	0.03	0.05			0.21	0.09	0.22	0.09	0.12		
Phosphate (mg/l P)	0.14		0.04		0.16	0.06	0.00	0.03			0.06	0.09	0.06	0.04	0.02			0.04	0.03	0.03	0.02	0.00			0.02	0.00	0.03	0.05	0.39		
Alkalinity (mg/l $CaCO_3$)	205		215		195	249	200	236			255	205	254	263	235			296	275	264	293	284			296	287	295	245	265		
Hardness (mg/l $CaCO_3$)	196		116			140		148			134	136	140		148			122		138		128			130		170		170		
Total Dissolved Solids(mg/l)														384	304			340									340	340	440		
Chloride (mg/l)					25							24		29					38	27						30		28			
Sulfate (mg/l)					28		48					28		19					22	22						22		22			

SOUTH TAHOE PUBLIC UTILITY DISTRICT - WATER RENOVATION PLANT
MONTHLY .BULATION OF FLOW AND LABORATORY DATA

NOVEMBER (Month) 1970 (Year)

	DATE																														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Plant Flow, M.G.	2.0	1.6	1.7	2.1	2.2	1.8	2.4	2.1	1.8	2.0	2.0	1.9	1.9	2.1	2.2	1.9	1.7	1.9	1.9	1.6	2.1	1.9	2.0	2.2	2.8	2.6	2.6	2.7	2.4	2.1	
Peak Flow Rate MGD	6.3	4.9	5.0	6.9	5.8	5.3	6.0	4.9	5.5	4.8	4.9	5.5	6.0	5.9	6.1	5.0	4.5	4.3	3.9	4.3	3.5	3.9	4.3	3.9	4.3	4.5	3.8	5.0	4.9	4.6	
Flow Into Indian Creek Reservoir, MG	2.0	1.6	1.7	2.1	2.2	1.8	2.4	2.1	1.8	2.0	2.0	1.9	1.9	2.1	2.2	1.9	1.7	1.9	1.9	1.6	2.1	1.9	2.0	2.2	2.8	2.6	2.6	2.7	2.4	2.1	
Flow From Indian Creek Reservoir, MG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Total Flow From Other Outlets, MG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
5-day BOD (mg/l)	1.5	0.8	1.0	0.1	0.6			0.6	1.7	1.1	0.5	0.8			0.8	1.3	1.3	1.2	0.2			0.9	0.5	0.6	0.8	0.7			0.7	0.5	
COD (mg/l)	9.9	10.6	9.9	8.6	6.9			8.9	7.7	7.7	6.5	7.6			6.2	8.3	14.1	6.8	6.8			5.7	2.0	2.8	3.6	2.8			6.4	5.2	
Suspended Solids (mg/l)	0	0	0	0	0			0	0	0	0	0			0	0	0	0	0			0	0	0	0	0			0	0	
M B A S (mg/l)	0.23	0.14	0.15	0.16	0.19			0.10	0.10	0.09	0.17	0.10			0.03	0.17	0.17	0.19	0.08			0.08	0.05	0.07	0.09	0.10			0.12	0.10	
Turbidity, J U	0.2	0.2	0.2	0.2	0.2			0.2	0.2	0.2	0.2	0.2			0.2	0.2	0.6	0.2	0.2			0.2	0.2	0.2	0.2	0.2			0.2	0.2	
pH (pH units)	7.2	7.2	7.3	7.2	7.1			7.1	7.7	7.2	7.2	7.1			7.1	7.3	8.1	7.5	7.5			7.3	7.2	7.3	7.7	7.2			6.9	7.3	
Chlorine Residual(mg/l)																															
Instantaneous	1.3	1.0	1.4	1.2	1.4			1.6	1.3	0.8	2.0	1.7			1.3	0.9	1.1	1.5	1.2				1.4	1.1	1.2	1.3			1.5	1.3	
30 Min. Contact																															
Luther Pass Station	0.9	1.0	0.6	0.6	0.6			1.0	1.0	1.0	0.8	1.1			0.9	0.9	0.7	1.1	0.9				0.9	0.9	0.7	0.9			0.0	0.8	
Coliforms (MPN/100 ml)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	
Nitrogen (mg/l N)																															
organic																															
ammonia	21.2	18.2	14.2	19.2				15.7		19.3	19.6				18.2	19.8	19.0	17.4	24.0			22.1		21.9	19.5	18.0			11.7	25.9	
nitrate	1.1	1.1	1.3	1.4	1.0			0.7	1.0	1.1	1.1	1.2			1.3	1.1	0.9	0.7	0.1			0.7	1.0	0.8	0.6	0.9			0.4	0.6	
nitrite	0.16	0.23	0.11	0.02	0.11			0.14	0.31	0.09	0.02	0.11			0.23	0.30	0.31	0.02	0.09			0.02	0.34	0.13	0.12	0.14			0.05	0.03	
Phosphate (mg/l P)	0.07	0.07	0.05	0.06	0.01			0.07	0.03	0.06	0.08	0.08			0.06	0.09		1.04	0.53			0.12	0.12	0.09	0.06	0.13			0.09	0.12	
Alkalinity (mg/l $CaCO_3$)	296	254	258	248	235			245	268	275	245	235			235	245	183	275	315			265	265	272	260	235			266	326	
Hardness (mg/l $CaCO_3$)	154	346	160		164			168		172		156			166		102		124			108				140			116	122	
Total Dissolved Solids(mg/l)				338	312			342	348	356	354	370			360		246	306	356												
Chloride (mg/l)		36		26					29		27					27		25					22		26					29	
Sulfate (mg/l)		26		26					31		23					22		33					28		23					22	

SOUTH TAHOE PUBLIC UTILITY DISTRICT - WATER RENOVATION PLANT
MONTHLY TABULATION OF FLOW AND LABORATORY DATA

DECEMBER (Month) 1970 (Year)

DATE

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Plant Flow, M G	1.9	1.9	2.0	2.0	2.2	2.2	1.9	2.2	2.3	2.3	1.5	2.4	2.1	2.0	2.2	2.1	1.6	2.0	2.1	2.3	2.2	2.3	2.3	2.6	2.5	3.0	3.0	3.1	2.3	3.2	3.2
Peak Flow Rate MGD	3.6	3.8	------------Recorder Out of Service------------											4.6	4.9	5.1	5.7	5.2	4.5	4.4	5.3	5.1	5.1	4.8	4.5	4.7	7.5	6.3	8.3	7.5	6.8
Flow Into Indian Creek Reservoir, MG	1.9	1.9	2.0	2.0	2.2	2.2	1.9	2.2	2.3	2.3	1.5	2.4	2.1	2.0	2.2	2.1	1.6	2.0	2.1	2.3	2.2	2.3	2.3	2.6	2.5	3.0	3.0	3.1	2.3	3.2	3.2
Flow From Indian Creek Reservoir, MG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Flow From Other Outlets, MG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5-day BOD (mg/l)	0.9	0.2	0.3			1.4	1.8	1.2	1.3	1.2			0.7	1.4	2.1	1.0	1.4			1.2	1.0				1.4		0.7		2.1	1.3	1.3
COD (mg/l)		3.4	8.0			6.8	6.0	6.8	6.4	9.2			15.2	16.8	16.8	14.8	12.0			17.6	20.6	8.8	26.0				18.7	17.6	18.7	20.7	
Suspended Solids (mg/l)	0	0	0			0	0	0	0	0			0	0	0	0	0			0	0	0	0	0			0	0	0	0	0
M B A S (mg/l)	0.07	0.09	0.12			0.12	0.11	0.15	0.16	0.12			0.31	0.10	0.36	0.32	0.31			0.39	0.41	0.41	0.36	0.37			0.45	0.48	0.43	0.52	0.49
Turbidity, J U			0.4			0.2	0.2	0.2		0.3			0.2	0.2	0.1	0.2	0.2			0.3	0.4	0.6	0.6	0.6				0.6	0.6	0.7	0.5
pH (pH units)	7.4	7.3	7.2			6.9	7.2	7.4	7.5	7.4			7.5	7.5	7.6	7.6	7.5			7.5	7.4	7.4	7.3	7.4			7.5	7.6	7.7	7.6	7.6
Chlorine Residual(mg/l)																															
Instantaneous			1.6			1.6	1.6	1.2	1.6	1.6			1.3	1.4	1.2	1.7	1.3			1.3	1.6	1.6	1.1	1.2			0.9	2.2		1.7	1.4
30 Min. Contact																															
Luther Pass Station			0.8			1.0	1.0	1.0	0.0	0.0			0.7	0.8	0.4	0.8	0.7			0.6	0.8	0.9	0.4	0.4			0.3	0.0		0.5	0.3
Coliforms (MPN/100 ml)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	8.8	38.0	<2.0	<2.0	<2.0	<2.0
Nitrogen (mg/1 N)																															
organic																															
ammonia	22.3	18.8	19.5			19.5	19.5		18.7	15.9			20.1	20.7	21.1	16.3	21.4			20.1	20.1	20.0	21.3	23.3			25.1	26.4	25.4	27.2	28.2
nitrate	0.5	0.9	0.9			0.5	0.5	0.8	0.7	0.9			0.9	0.5	0.1	0.0	0.1			0.1	0.0	0.1	0.0	0.0			0.2	0.2	0.4	0.1	0.0
nitrite	0.02	0.03	0.05			0.08	0.19	0.08	0.04	0.05			0.01	0.08	0.19	0.01	0.01			0.01	0.01	0.01	0.02	0.01			1.01	0.01	0.02	0.01	0.01
Phosphate (mg/l P)	0.04	0.06	0.04			0.20	0.19	0.10	0.10	0.18			0.02	0.16	0.12	0.11	0.07			0.05	0.09	0.05		0.02				0.07	0.09	0.09	
Alkalinity (mg/l $CaCO_3$)	325	315	235			270	249	266	232	225			297	245	218	277	255			300	269	265	267	269			258	235	240	280	256
Hardness (mg/l $CaCO_3$)	134		126			142	122	140	130	174			190	154	132	162	202			172	172	182	184	214			186	148	160	164	199
Total Dissolved Solids(mg/l)										318			[illegible]	276	278	294	328				300										
Chloride (mg/l)		22					29		26					28	51						26		22					40		26	
Sulfate (mg/l)		22					23		48					10	22						23		28					56		56	

FIGURE C-1

COD ISOTHERM
VIRGIN CARBON
FEBRUARY 1968

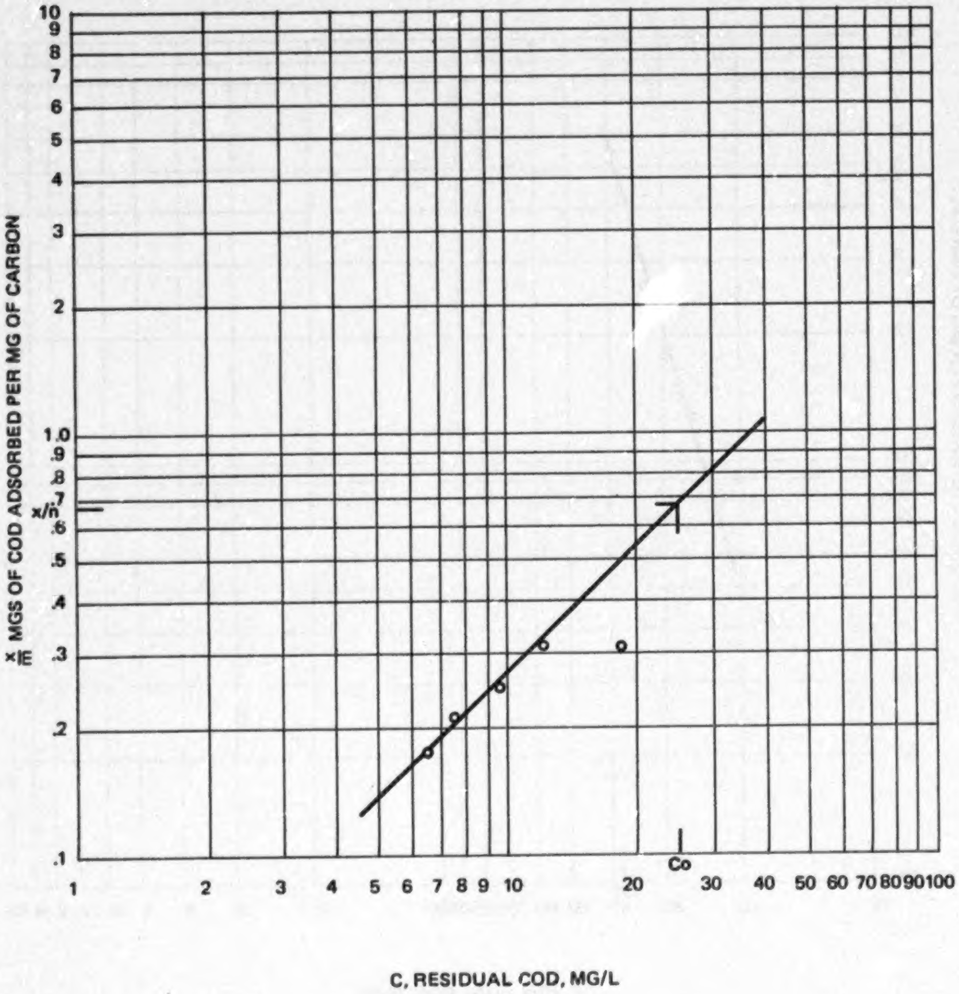


FIGURE C-2

COD ISOTHERM
CC-5 SPENT
DECEMBER 1968

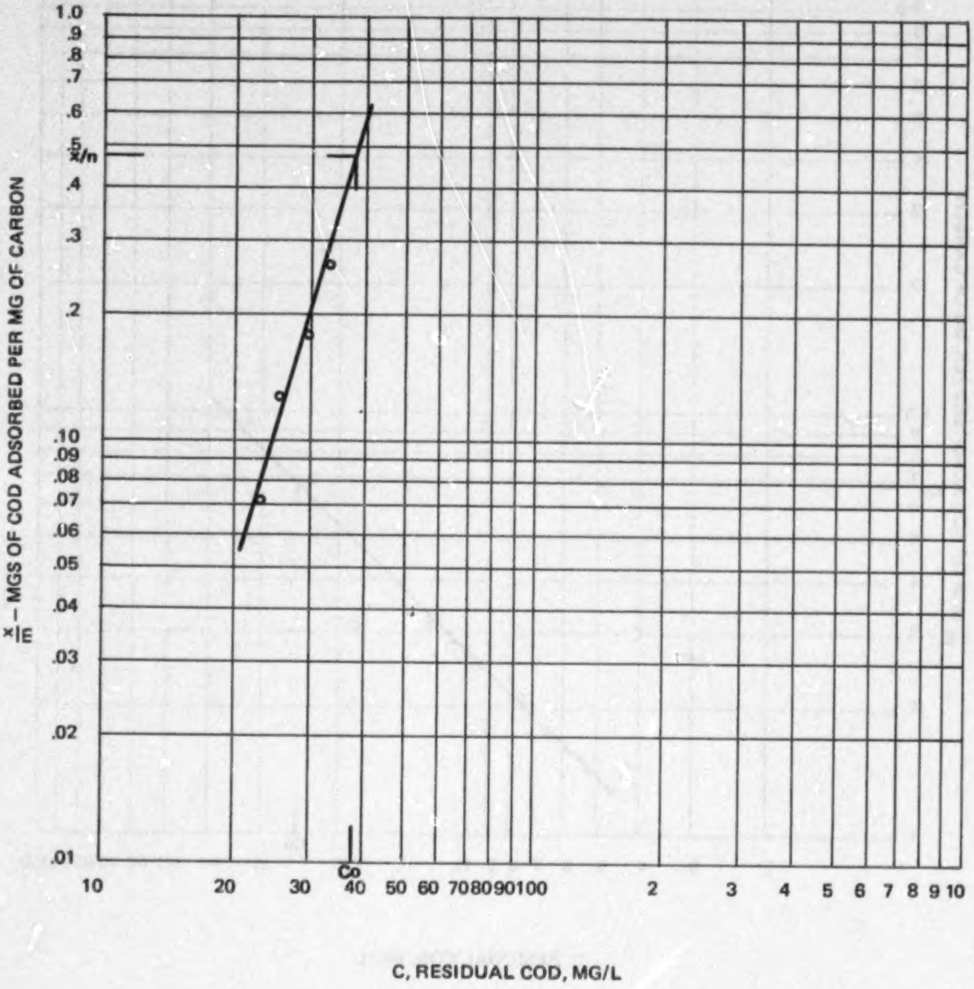


FIGURE C-3

COD ISOTHERM
CC-5 REGENERATED
DECEMBER 1968

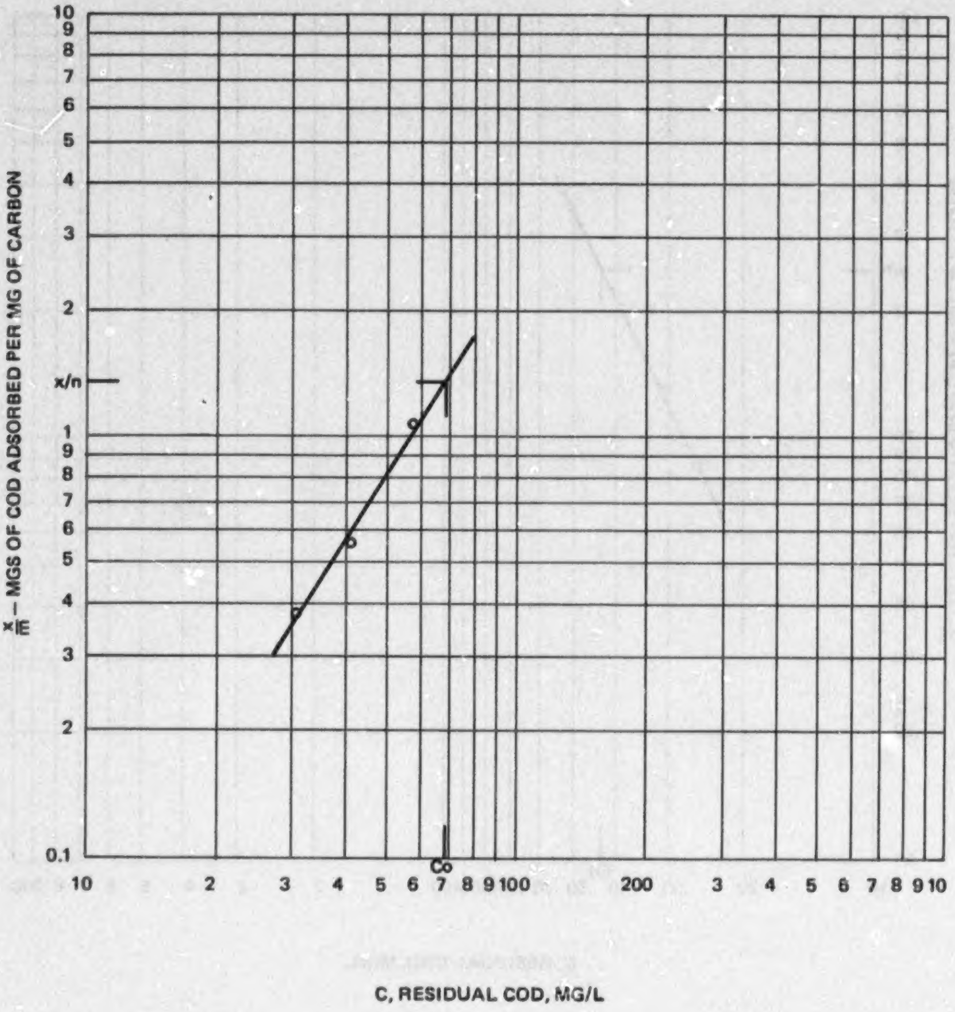


FIGURE C-4

COD ISOTHERM
CC-5 SPENT
JANUARY 1970

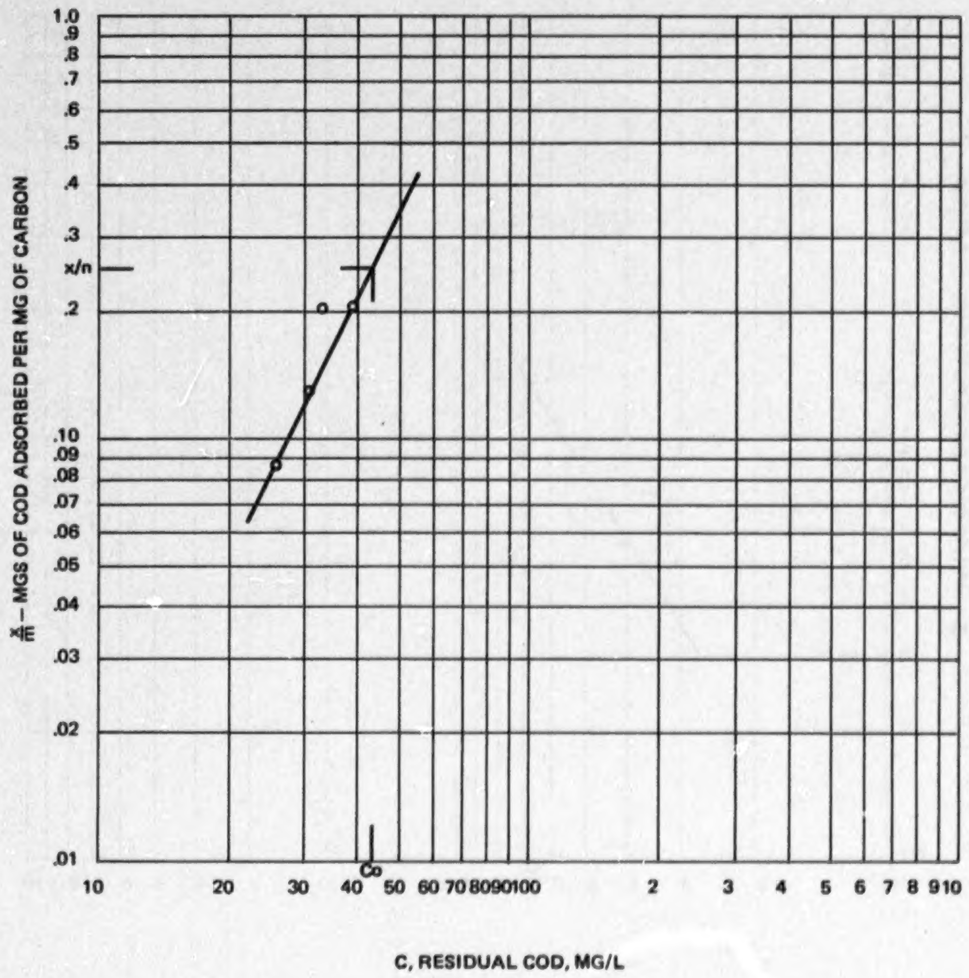


FIGURE C-5

COD ISOTHERM
CC-5 REGENERATED
JANUARY 1970

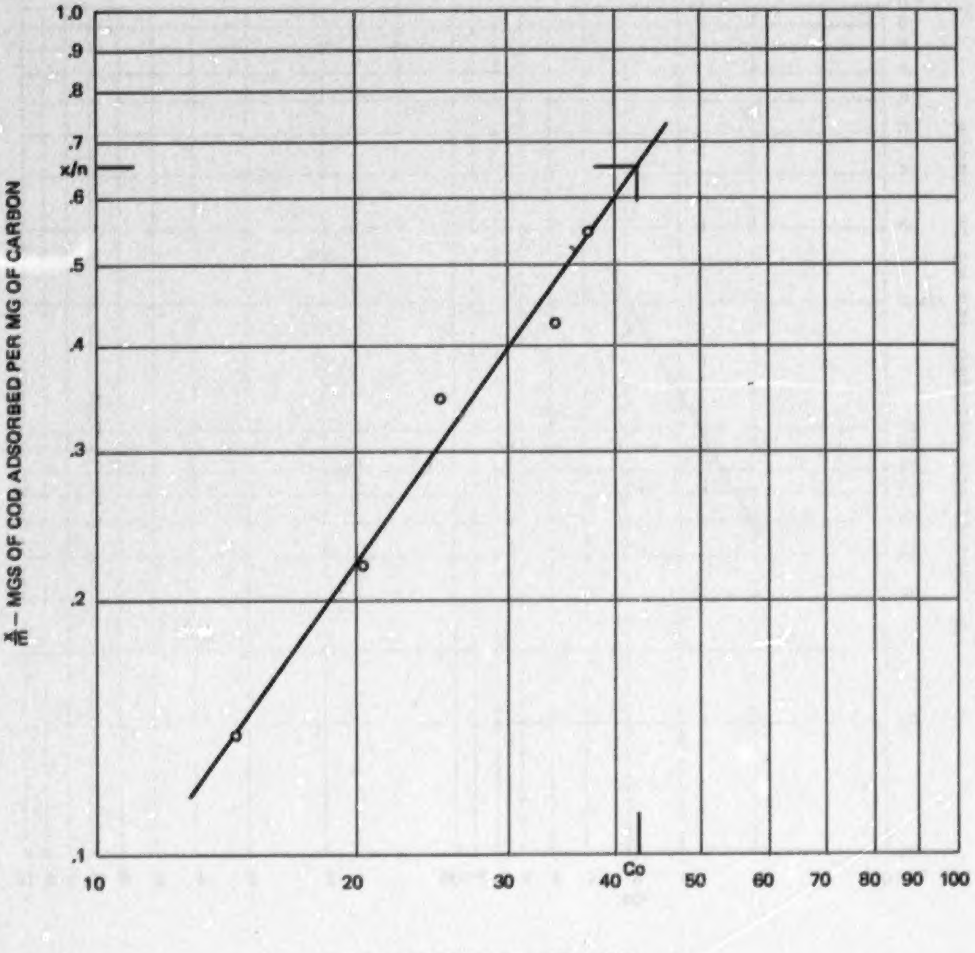
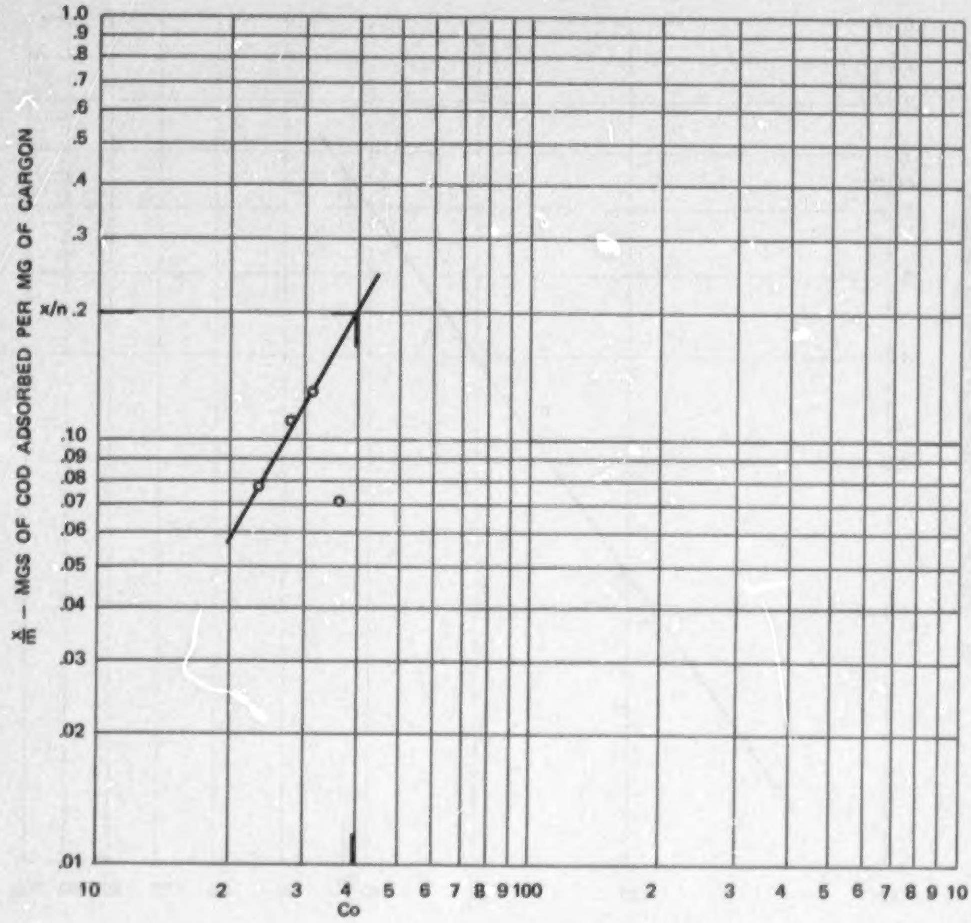


FIGURE C-6

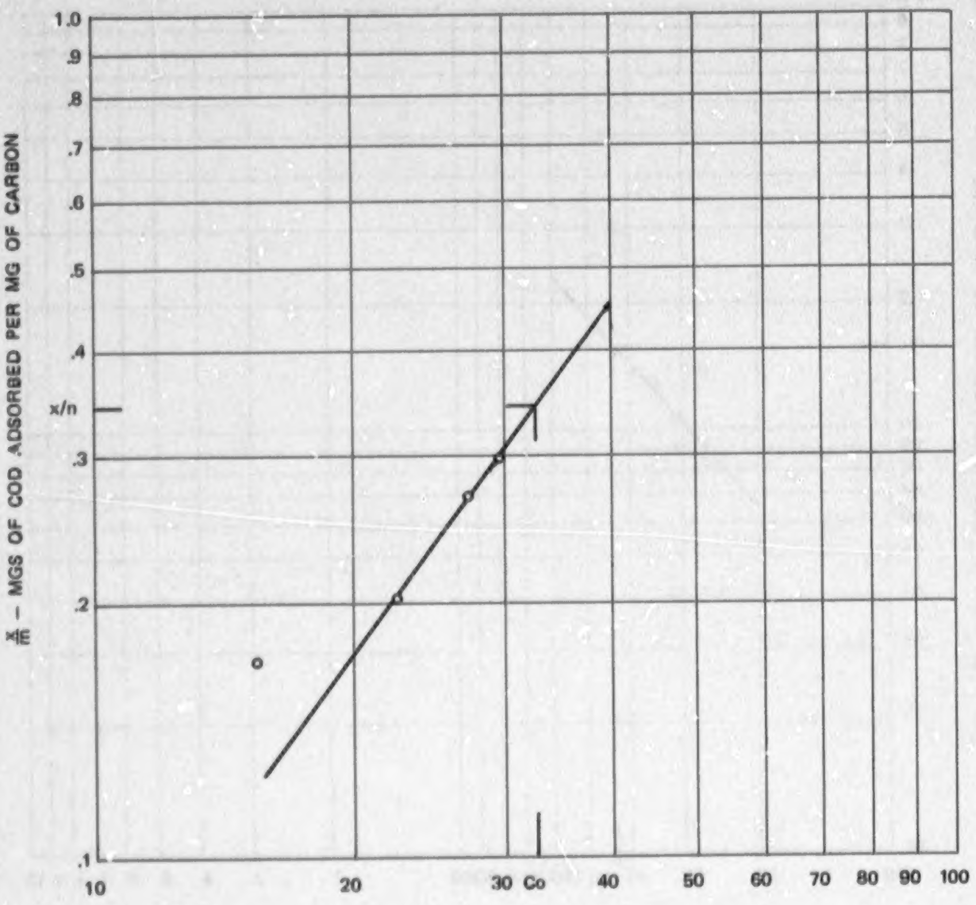
COD ISOTHERM
CC-5 SPENT
NOVEMBER 1970



C, RESIDUAL COD, MG/L

FIGURE C-7

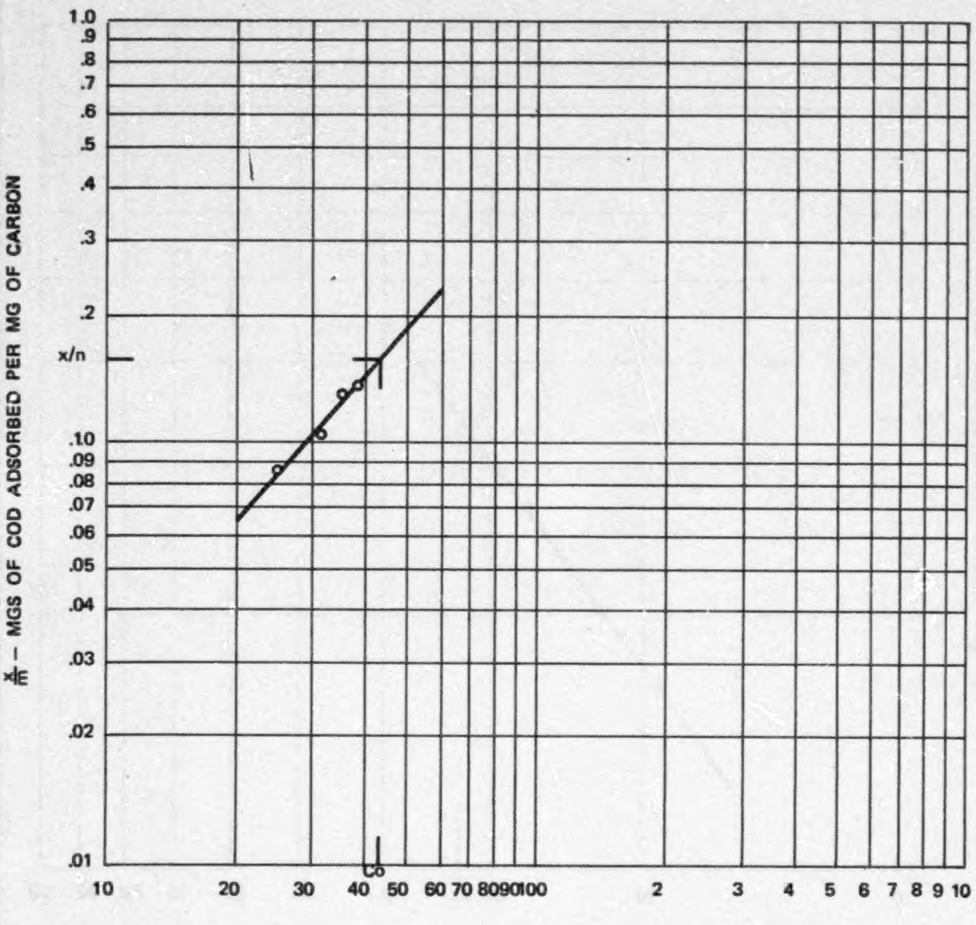
COD ISOTHERM
CC-5 REGENERATED
NOVEMBER 1970



C, RESIDUAL COD, MG/L

FIGURE C-8

COD ISOTHERM
CC-8 SPENT
JULY 1970



C, RESIDUAL COD, MG/L

FIGURE C-9

COD ISOTHERM
CC-8 REGENERATED
JULY 1970

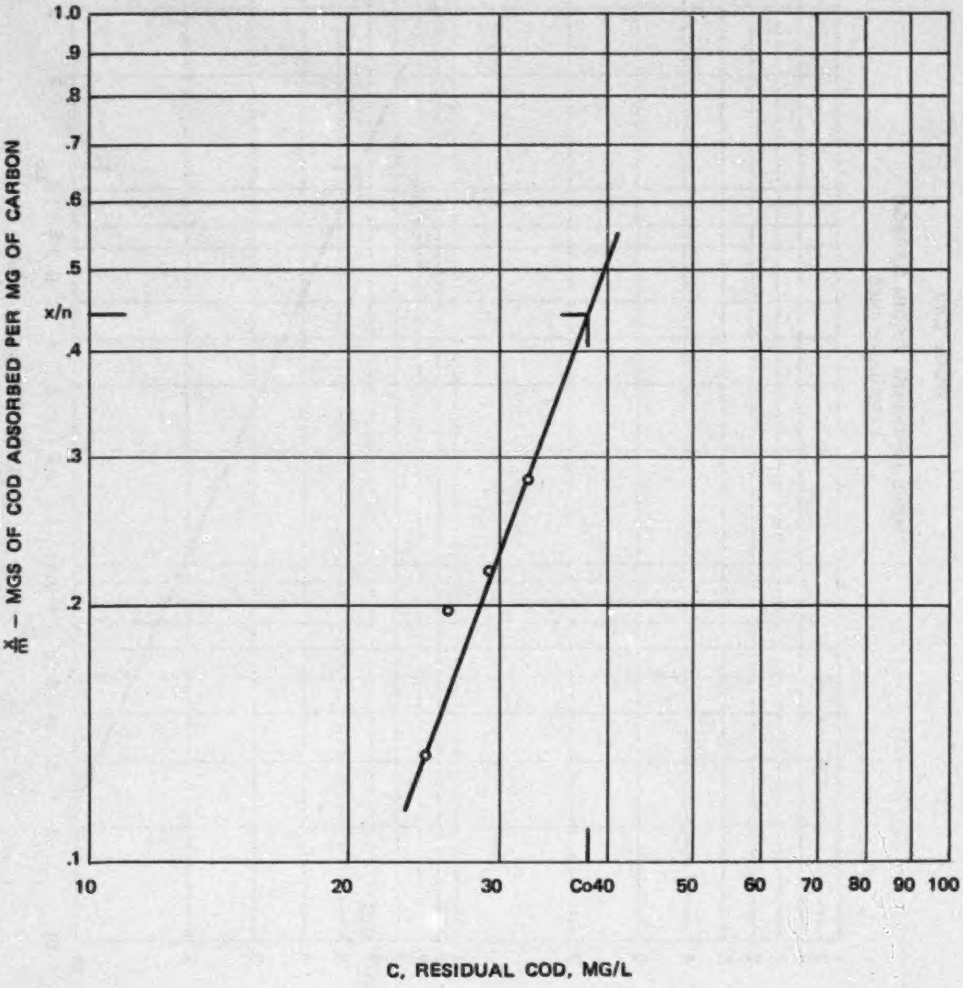


FIGURE C-10

MBAS ISOTHERM VIRGIN CARBON
FEBRUARY 1968

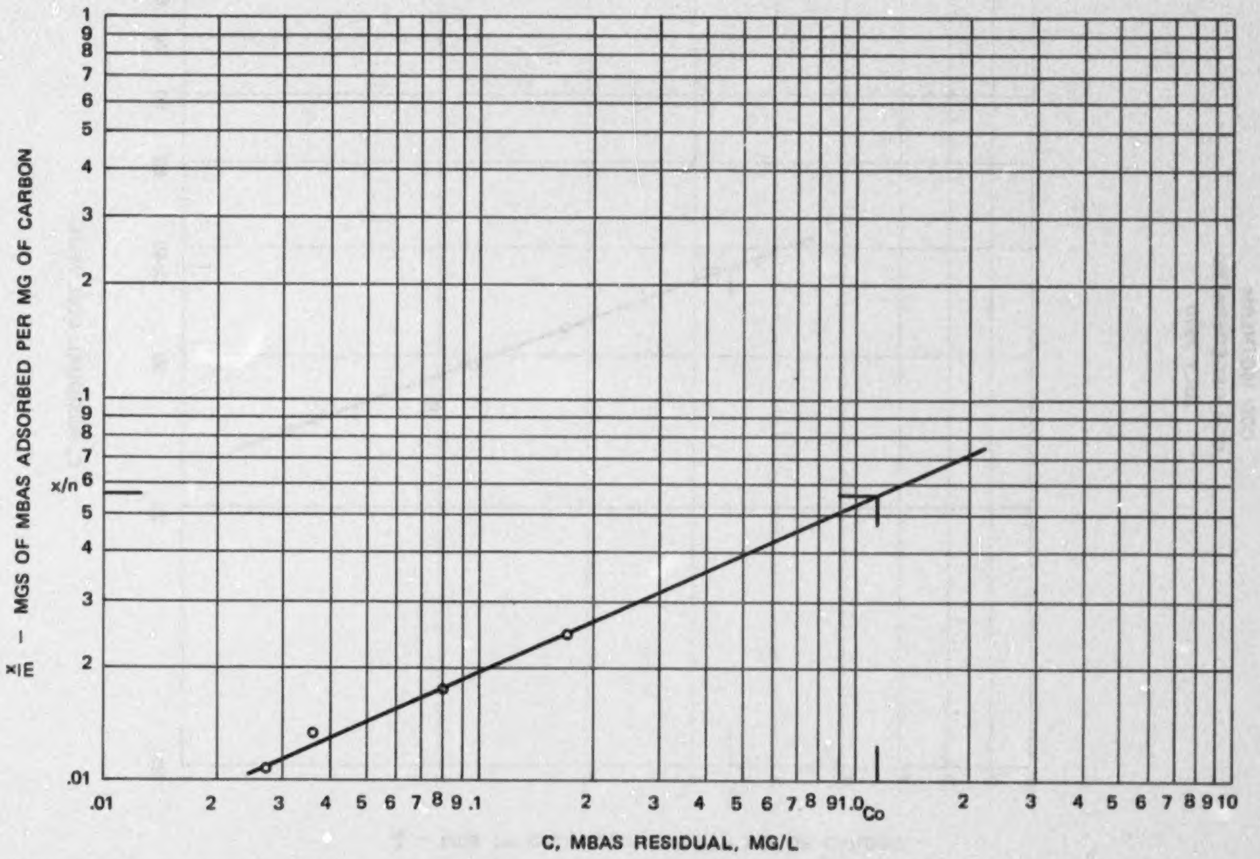


FIGURE C-11

MBAS ISOTHERM CC-5 SPENT
DECEMBER 1968

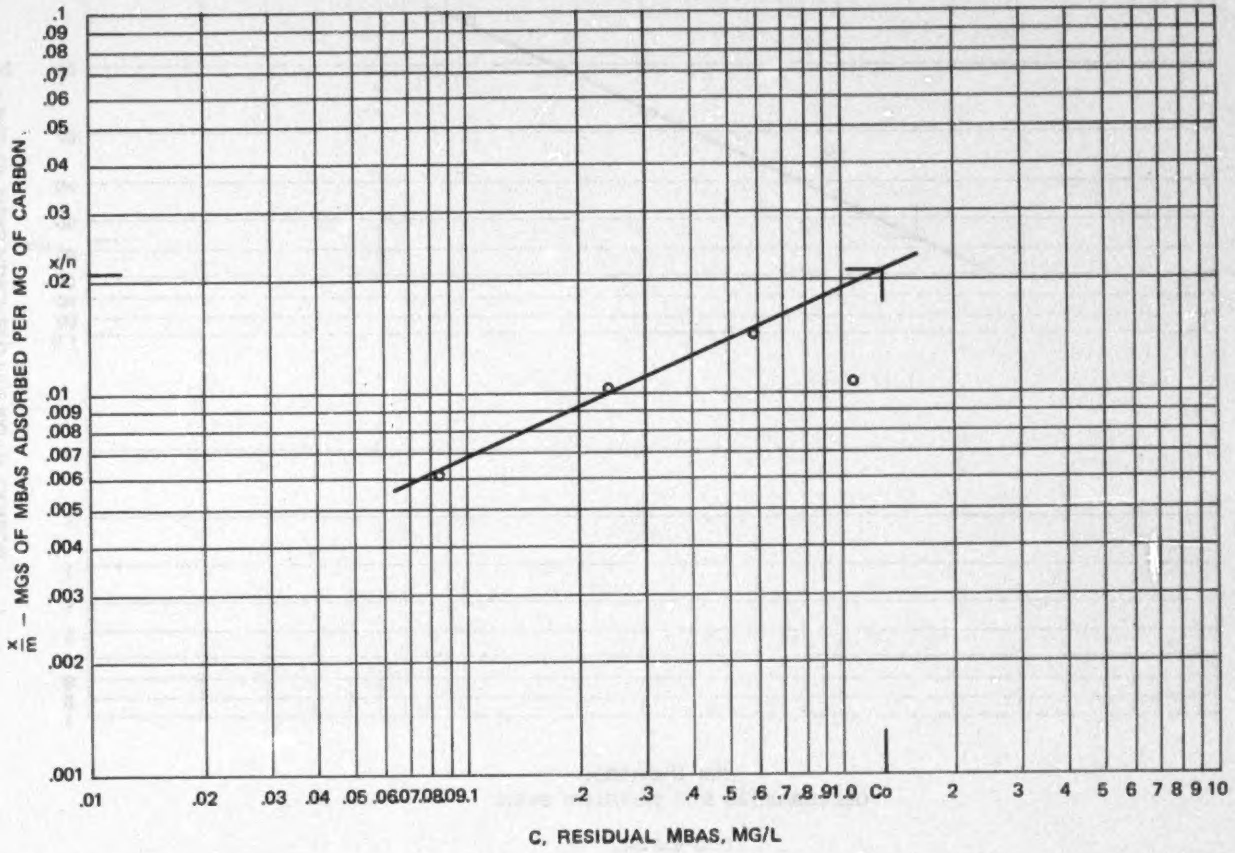


FIGURE C-12

MBAS ISOTHERM CC-5 REGENERATED
DECEMBER 1968

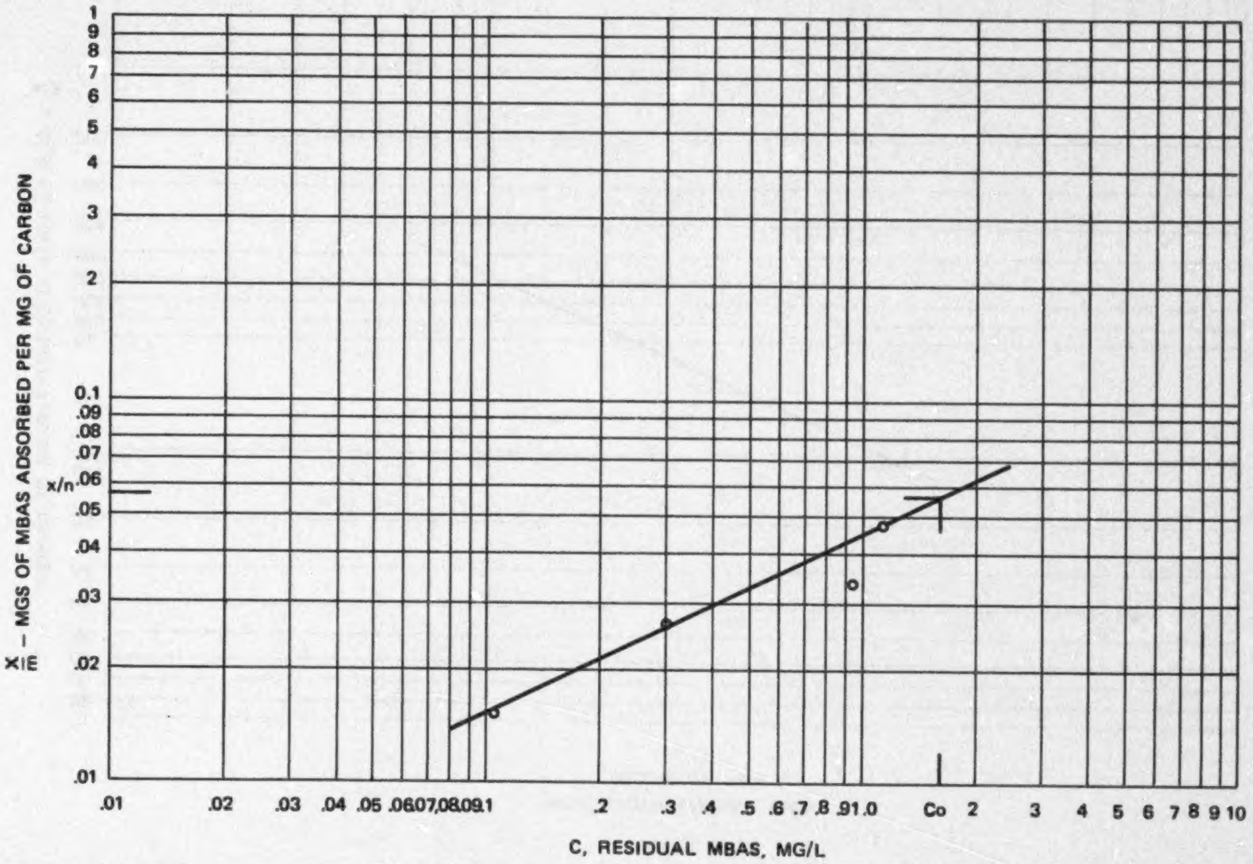


FIGURE C-13

MBAS ISOTHERM CC-5 SPENT
JANUARY 1970

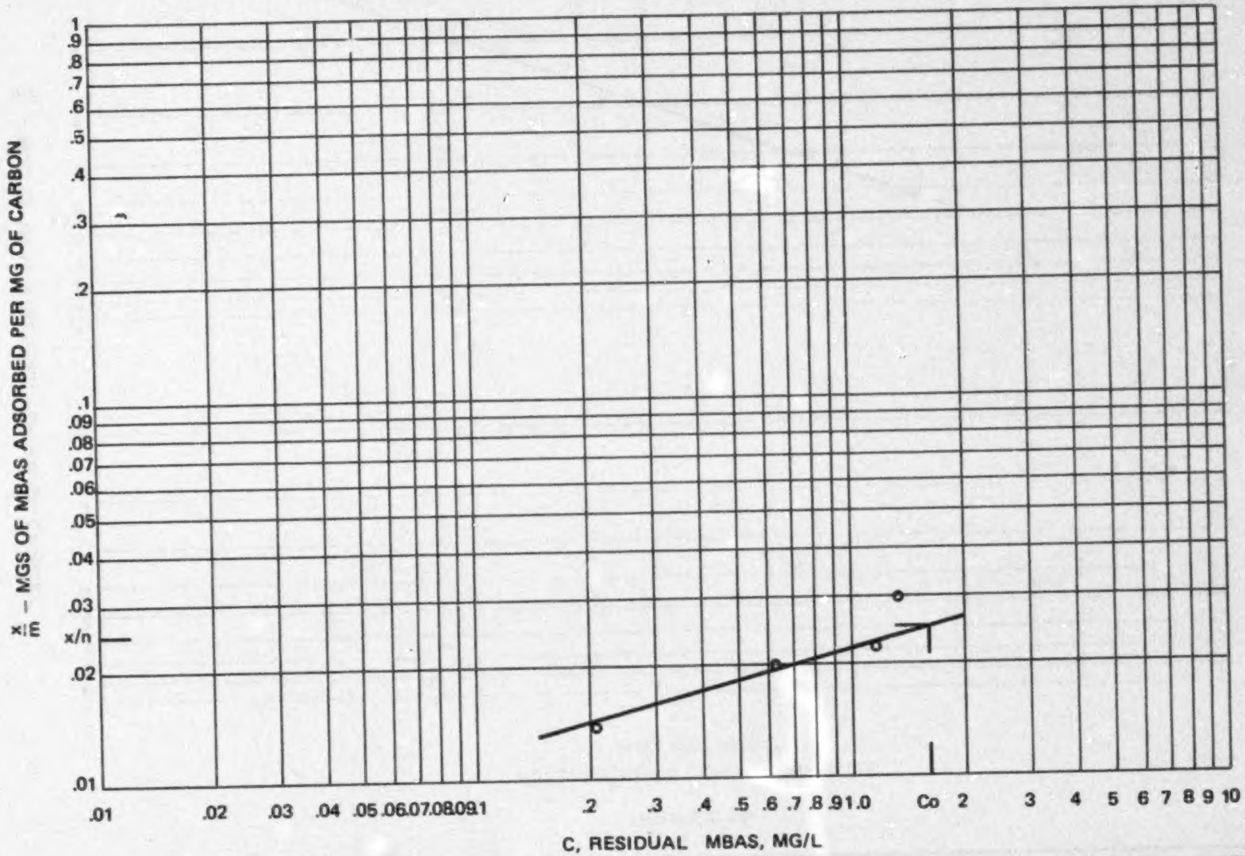


FIGURE C-14

MBAS ISOTHERM CC-5 REGENERATED
JANUARY 1970

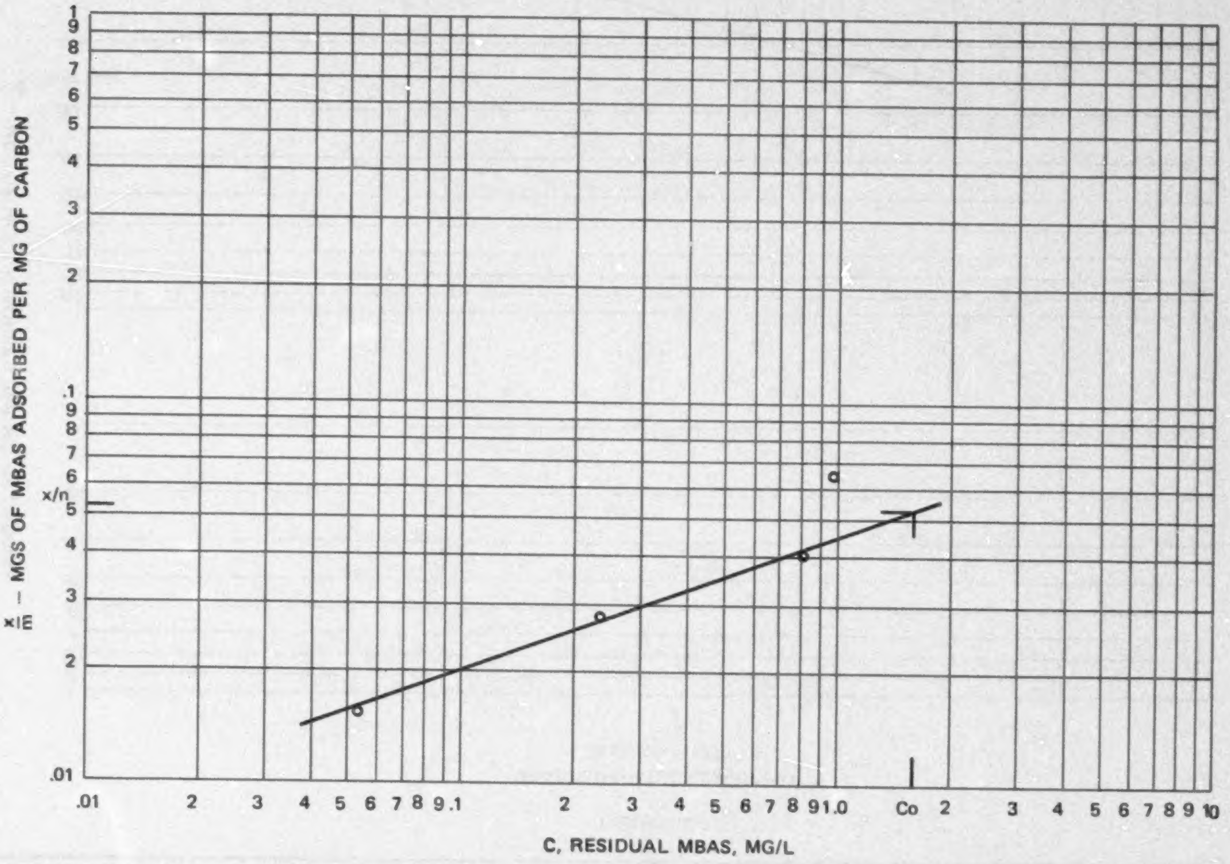


FIGURE C-15

MBAS ISOTHERM CC-5 SPENT
NOVEMBER 1970

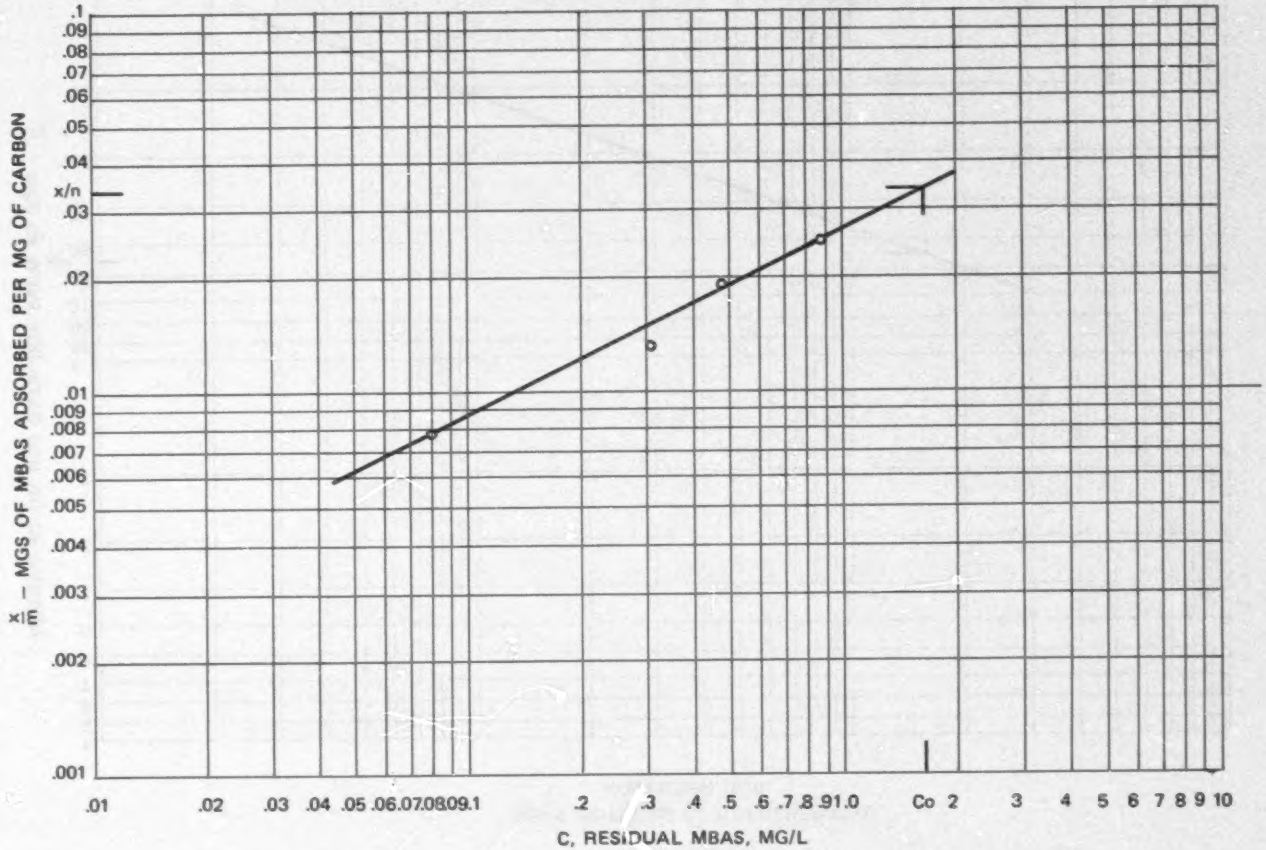


FIGURE C-16

MBAS ISOTHERM CC-5 REGENERATED
NOVEMBER 1970

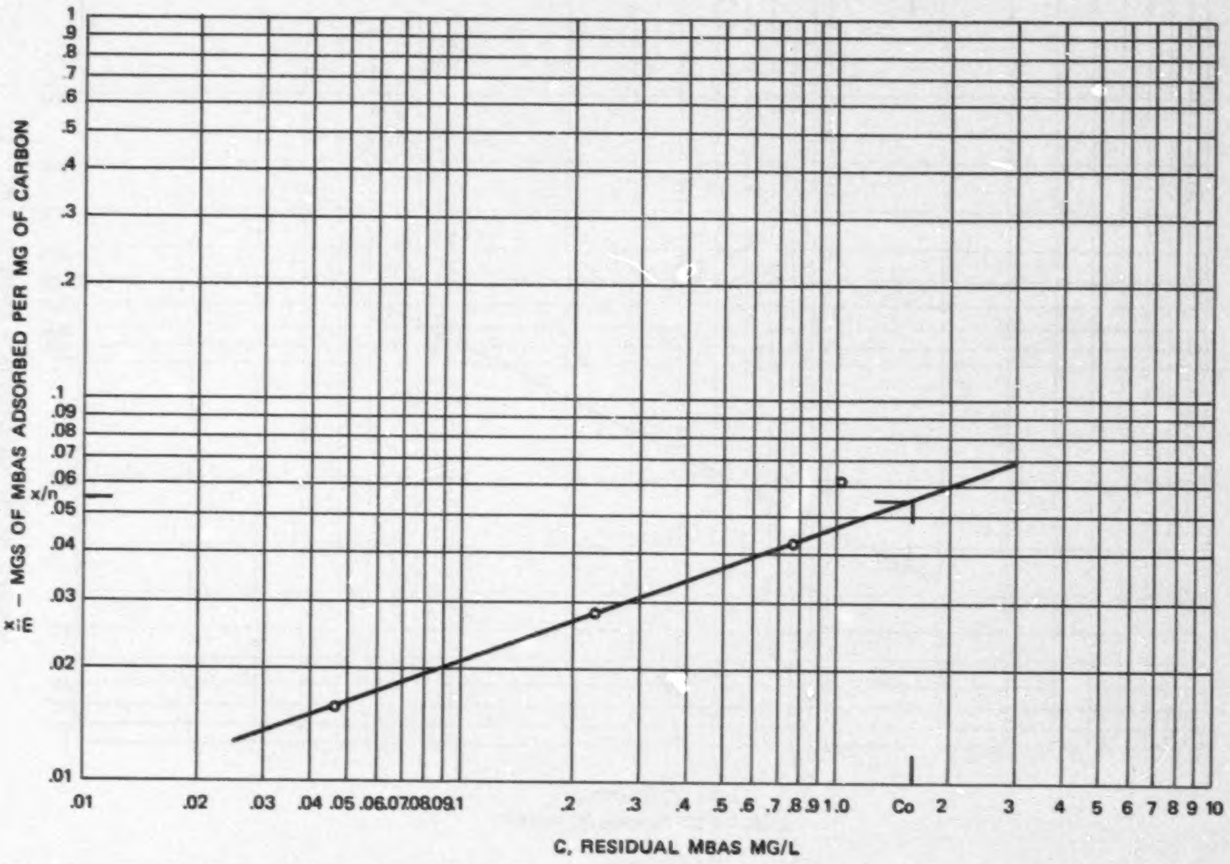


FIGURE C-17

MBAS ISOTHERM CC-8 SPENT

JULY 1970

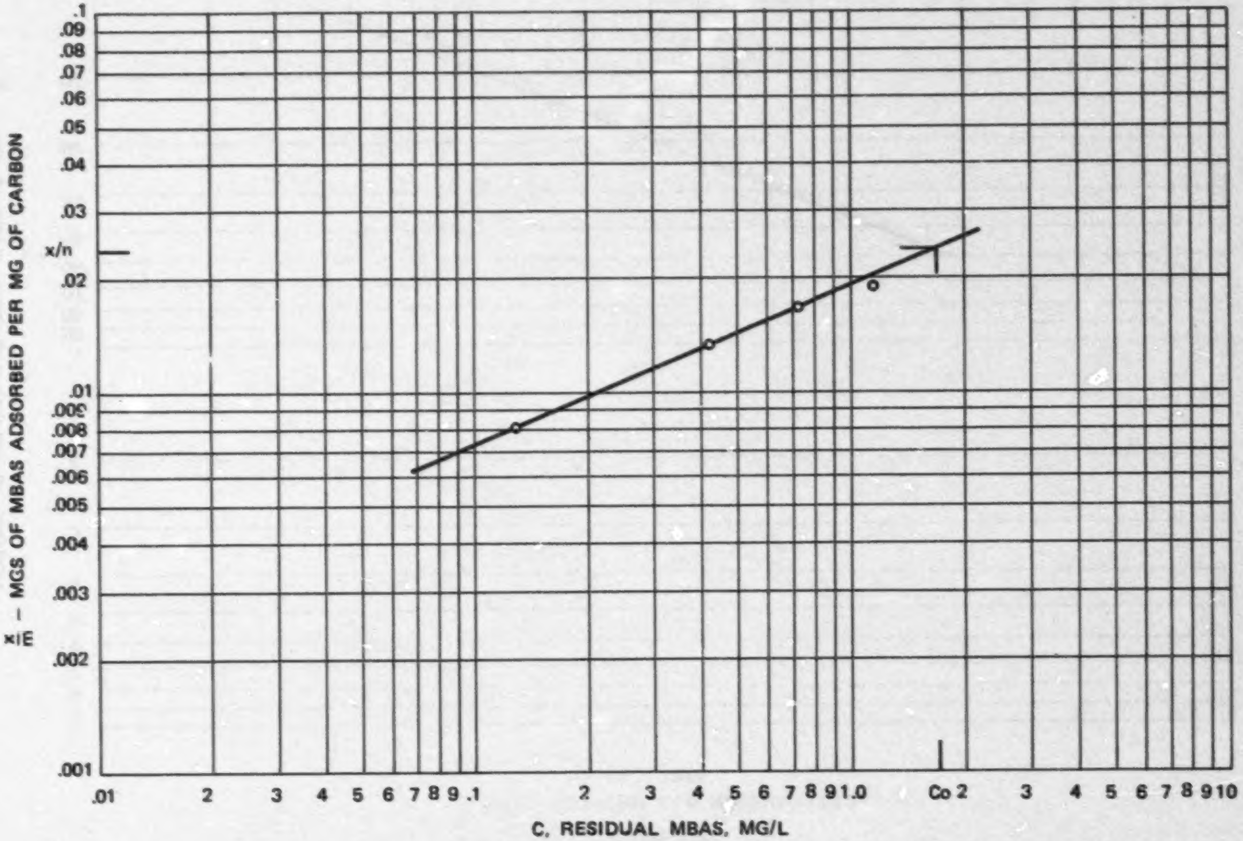


FIGURE C-18

MBAS ISOTHERM CC-8 REGENERATED
JULY 1970